Tissue Harmonic Imaging, Frequency Compound Imaging, and Conventional Imaging

Use and Benefit in Breast Sonography

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Objective. The purpose of this study was to evaluate different sonographic settings (tissue harmonic, frequency compounding, and conventional imaging) and to determine which setting optimizes breast lesion detection and lesion characterization.

Methods. Four hundred thirteen consecutive breast lesions (249 benign and 164 malignant) were evaluated by sonography using 4 different modes (conventional imaging at 14 MHz, tissue harmonic imaging at 14 MHz [THI], and frequency compound imaging at 10 MHz [CI10] and 14 MHz [CI14]). The images were reviewed by consensus by 2 breast radiologists. For each image, the lesion was graded for conspicuity, mass margin assessment, echo texture assessment, overall image quality, and posterior acoustic features.

Results. For lesion conspicuity, THI and CI14 were better than conventional imaging (P < .01) and CI10 (P < .01) particularly against a fatty background (P < .01 for THI versus conventional for a fatty background versus P = .13 for a dense background). Frequency compound imaging at 10 MHz performed the best in echo texture assessment (P < .01), as well as overall image quality (P < .01). For margin assessment, CI10 performed better for deep and large (≥1.5-cm) lesions, whereas CI14 performed better for small (<1.5-cm) and superficial lesions. Finally, THI and CI14 increased posterior shadowing (P < .01) and posterior enhancement (P < .01).

Conclusions. The standard breast examination incorporates 2 distinct processes, lesion detection and lesion characterization. With respect to detection, THI is useful, especially in fatty breasts. With respect to characterization, compound imaging improves lesion echo texture assessment. No single setting in isolation can provide the necessary optimized information for both of these tasks. As such, a combination approach is best. Key words: breast neoplasms, diagnosis; breast neoplasms, sonography; sonography, harmonic study.

Sonographic examination of a breast lesion entails 2 different and necessary steps: detection and characterization. Clinical practice has shown that the detection or characterization of a mass might be limited in different scenarios. Recently, new sonographic modes such as compound imaging and tissue harmonic imaging (THI) have been added to standard breast sonography. They are expected to improve both detection and characterization of breast masses; nevertheless, their contribution has been rarely evaluated.

Tissue harmonic imaging creates images derived solely from the higher frequencies. Different techniques (frequency filtering, pulse inversion/phase cancellation, and coded harmonics) can be used to process the received...
signal so that only the returning high-frequency harmonic signal is used to produce the image, whereas echoes from the fundamental frequencies are rejected. Tissue harmonic imaging increases signal-to-noise ratio, resulting in better tissue contrast. Tissue harmonic imaging has been reported to improve conspicuity, lesion border and content definition, and acoustic shadow conspicuity of breast lesions. However, THI would be of limited value in differentiating benign from malignant lesions.

Compound imaging is a different technology that has the ability to acquire multiple frames from different frequencies (frequency compound imaging) or from different angles (spatial compound imaging) and to combine these to form a single, multifrequency or multangle compound image (frequency and spatial compound imaging, respectively). Mostly spatial compounding has been evaluated in breast imaging, showing improvement in image quality, in conspicuity of low-contrast lesions, and in lesion margin and content definition, but would be of limited value in differentiating benign from malignant lesions. Frequency compounding, which was used in our study, has only been evaluated in interventional breast sonography. Frequency compounding is the combination of multiple transmitted images detected from different frequency bands, with 2 different center frequencies (10 and 14 MHz) into a single compound image.

Our study had 3 purposes: (1) to compare the performance of different sonographic settings available on our sonographic apparatus; (2) to determine which setting optimized lesion detection; and (3) to determine which setting optimized lesion characterization.

Materials and Methods

In our clinical practice, we routinely use the different settings available on our sonographic apparatus. Therefore, we decided to retrospectively evaluate these different sonographic settings (THI, frequency compound imaging at 10 MHz [CI10] and 14 MHz [CI14], and conventional imaging) with respect to their advantages and limitations in the detection and characterization of breast lesions appearing in different situations, especially in relation to the background breast environment (fatty versus glandular), the type of lesion (solid versus cystic), and lesion size and location (superficial versus not superficial).

Imaging Protocol

Part of our practice is to routinely evaluate all breast abnormalities identified at sonographic examination with the different settings available on our sonographic apparatus. Between December 2001 and June 2002, it was standard of care at our institution for all breast lesions identified sonographically to be examined with the 4 different imaging modes (conventional imaging at 14 MHz, CI10, CI14, and THI at 14 MHz) available on our sonographic apparatus (Acuson Sequoia scanner [Siemens Medical Solutions, Mountain View, CA] used with an 15L8w 8- to 15-MHz high-resolution linear array transducer). All images were acquired by 2 breast radiologists (B.M. and E.K.). All studies were stored on our picture archiving and communication system. For each examination, the focal zone was set at the lesion’s depth. In cases of a superficial lesion, no acoustic standoff pad was used. Similar images in terms of projection were taken with each mode. In 2004, a set of 4 sonograms of the same lesion using the 4 different modes was selected by 1 radiologist (T.H.). This set of 4 images constituted the examination to be evaluated (Figures 1–4).

Sonographic examination of all breast lesions using the different settings available on our sonographic apparatus with image storage was being performed for the initial purpose of adaptation to our newly acquired sonographic apparatus and subsequently as a part of routine care at our institution. Our Research Ethics Board considered this practice as innovative care and did not require its additional approval. Permission was obtained from the hospital for review of the patients’ medical records.

Image Interpretation

Images were displayed on a picture archiving and communication system workstation and then evaluated by consensus by 2 authors (B.M. and M.E.-K.) more than 2 years after their
acquisition. The radiologists were blinded to the patient information, pathologic diagnosis, follow-up findings, and sonographic settings by monitor overlays. They determined the depth and the size of each lesion and the surrounding tissue. For each case, the readers had access to all 4 images randomly organized. The 2 readers were specialists in breast imaging with 10 and 5 years of experience. Both had more than 3 years of experience with CI and THI. They were asked to assess the following criteria: overall image quality, lesion conspicuity, mass margin assessment, echo texture assessment, and posterior acoustic phenomena. Overall image quality was defined as a general assessment encompassing spatial resolution or detail and absence of noise. Lesion conspicuity was defined as the visibility and clarity of the lesion compared with the adjacent structures. With respect to mass margin assessment, the readers evaluated and graded the capacity of each setting to properly visualize the mass margins. With respect to echo texture assessment, the readers evaluated and graded the capacity of each setting to determine the echo texture of the mass. With respect to acoustic phenomena, the readers identified the type of posterior echoes (enhanced, unaffected, or decreased). Once determined, the acoustic phenomena (enhancement or shadowing) were graded with each setting. A 5-point ordinal scale was used, with grade 1 being the worst and grade 5 the best. In the case of posterior acoustic phenomena, grade 1 corresponded to the more neutral effect and grade 5 to the more amplified effect.

Figure 1. Images from a 79-year-old patient with a history of left breast carcinoma who had a new contralateral spiculated mass on mammography (not shown) (BI-RADS category 5). Sonography showed a 5-mm irregular mass displaying indistinct margins and a heterogeneous echo texture (mildly hyperechoic) at the 12-o’clock position in the right breast. Sonographically guided 14-gauge core needle biopsy yielded invasive ductal carcinoma. A, Conventional imaging. B, Frequency compound imaging at 10 MHz. C, Frequency compound imaging at 14 MHz. D, Tissue harmonic imaging. Lesion conspicuity is significantly better with CI14 (C) and THI (D) because better contrast resolution and accentuated posterior shadowing are shown. Mass margins and echo texture are better shown with conventional imaging (A) and CI10 (B).
Patients
A retrospective study was performed of 413 consecutive breast lesions in 360 patients (from December 2001 to June 2002). Information summarizing the characteristics of the study population is shown in Table 1. All patients were women. The mean patient age was 55 years (range, 18–83 years). The longest dimensions of the lesions ranged from 0.2 to 4 cm (mean, 1.2 cm). Histologic tissue examination showed 164 malignant lesions (39.7%); 249 lesions (60.3%) were benign. Benignity was ascertained on core needle biopsy (14-gauge needle; n = 67), fine-needle aspiration (22-gauge needle) and sonographic follow-up (n = 24), sonographic follow-up alone (>1 year; n = 54), or because of the pathognomonic sonographic appearance (cysts, intramammary lymph nodes, or siliconoma; n = 104). Surrounding tissue was fatty in 202 (48.9%) and glandular in 211 (51.1%).

Statistical Analysis
The statistical analysis of the data was performed using SAS software (PROC REG, PROC UNIVARIATE, and PROC FREQ; SAS Institute Inc, Cary,

Figure 2. Images from a 56-year-old patient with an 8-mm well-circumscribed, lobulated solid mass surrounded by a fatty background (BI-RADS category 3). Sonographically guided 14-gauge core needle biopsy yielded a fibroadenoma. A, Conventional imaging. B, Frequency compound imaging at 10 MHz. C, Frequency compound imaging at 14 MHz. D, Tissue harmonic imaging. Posterior shadowing is amplified with THI (D), and contrast between the lesion and surrounding fatty tissue is increased with THI and CI14, leading to better conspicuity with these 2 settings (C and D). The echo texture of the mass is better shown with CI10 (B), as well as its contours. Note that the contours (anterior aspect of the mass) are not clearly shown with THI (D, arrow).
NC). Initial analyses were paired $t$ tests and Wilcoxon signed rank tests, used for comparing all pairs of settings (conventional at 14 MHz versus CI10 versus CI14 versus THI). Multivariate analyses were done with linear regression, regressing explanatory factors (age, malignant or not, fatty or dense, shallow or deep, size, and lesion texture) on the difference in ranking (0–4, from none to excellent) between every pair of settings. Thus each ranking difference is a number from –4 to +4. There were 6 pairs from 4 settings. A design factor, order effect, was also entered in the regressions because we found some associations between the rankings and in

**Figure 3.** Images from a 35-year-old patient with a 7-mm round complex mass superficially located within a fatty surrounding background (BI-RADS category 4). Sonographically guided 14-gauge core needle biopsy yielded an intracystic papilloma without atypia, confirmed by surgical excision. **A**, Conventional imaging. **B**, Frequency compound imaging at 10 MHz. **C**, Frequency compound imaging at 14 MHz. **D**, Tissue harmonic imaging. Conspicuity of the lesion is slightly better with THI (D) and CI14 (C). Echo texture assessment is significantly better with CI10 (B) and CI14 (C), particularly with respect to the small cystic components. Contour delineation is better with CI14 (C, arrow).
what order the 4 settings were assessed for each patient’s image. To correct for this bias, every rank difference for 2 settings was regressed on the corresponding order effect, which was the numerical difference in order (1–4) for the 2 settings. Thus, the order effect is a number from –3 to +3. The results reported as Δ shown in Tables 2–5 are the values of the intercept for the regression of the order effect on the difference in rank between 2 settings, whether the order effect was statistically significant. Also shown is the lower bound of the 95% confidence interval for Δ as explained in the table footnotes. Where more than 2 consecutively ranked settings are shown as not significantly different, the first is also not significantly different from the last, unless such significance is indicated in the footnotes. All multivariate analyses included the order effects.

**Results**

**Lesion Conspicuity**

With a fatty background, CI14 and THI significantly improved lesion conspicuity, particularly...
with lesions smaller than 1.5 cm. In the context of a glandular background, no setting performed significantly better than conventional imaging. In cases of superficially located lesions, CI14 improved lesion conspicuity better than THI, and both of these performed better than conventional imaging (Table 2 and Figures 1 and 2).

### Margin Assessment

In the overall comparison of the settings, no setting was significantly better than conventional imaging, whereas THI was the worst setting. Frequency compound imaging at 10 MHz significantly improved margin assessment in the case of a large (≥1.5-cm) nonsuperficial lesion, whereas CI14 significantly improved margin assessment in the case of a small (<1.5-cm) superficial lesion (Table 3 and Figures 2 and 4).

### Echo Texture Assessment

In the overall evaluation, as well as for each of the different individual categories (solid, cystic, and solid and cystic), CI was the best setting for echo texture assessment. It was significantly better than conventional imaging. Tissue harmonic imaging was the worst setting (Table 4 and Figures 1–4).

### Acoustic Phenomena

When acoustic enhancement or attenuation was present, THI and CI14 significantly amplified these phenomena, whereas CI10 was the setting that significantly diminished these (Table 5 and Figures 1 and 4).

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**Table 1. Lesion Characteristics**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Category</th>
<th>Lesions, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size, cm</td>
<td>≥1.5</td>
<td>73 (17.7)</td>
</tr>
<tr>
<td></td>
<td>&lt;1.5</td>
<td>340 (82.3)</td>
</tr>
<tr>
<td>Background</td>
<td>Fatty</td>
<td>202 (48.9)</td>
</tr>
<tr>
<td></td>
<td>Glandular</td>
<td>211 (51.1)</td>
</tr>
<tr>
<td>Diagnosis</td>
<td>Benign</td>
<td>249 (60.3)</td>
</tr>
<tr>
<td></td>
<td>Malignant</td>
<td>164 (39.7)</td>
</tr>
<tr>
<td>Texture</td>
<td>Cystic</td>
<td>91 (22.0)</td>
</tr>
<tr>
<td></td>
<td>Solid</td>
<td>281 (68.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>125 benign, 156 malignant</td>
</tr>
<tr>
<td></td>
<td>Cystic and solid</td>
<td>41 (9.9)</td>
</tr>
<tr>
<td>Depth, cm</td>
<td>Superficial (0–1)</td>
<td>154 (37.3)</td>
</tr>
<tr>
<td></td>
<td>Not superficial (&gt;1)</td>
<td>259 (62.7)</td>
</tr>
</tbody>
</table>

**Table 2. Lesion Conspicuity**

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Lesions, n</th>
<th>Ranked Best</th>
<th>Δ</th>
<th>ΔLB</th>
<th>Ranked Best</th>
<th>Δ</th>
<th>ΔLB</th>
<th>Ranked Best</th>
<th>Δ</th>
<th>ΔLB</th>
<th>Ranked Best</th>
<th>Δ</th>
<th>ΔLB</th>
<th>Ranked Best</th>
<th>Δ</th>
<th>ΔLB</th>
<th>Ranked Best</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatty background</td>
<td>202</td>
<td>CI14</td>
<td>0.05</td>
<td>-0.01</td>
<td>THI</td>
<td>0.47</td>
<td>+0.32</td>
<td>14</td>
<td>0.37</td>
<td>+0.24</td>
<td>CI10</td>
<td>0.68</td>
<td>+0.24</td>
<td>CI10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glandular background</td>
<td>211</td>
<td>CI14</td>
<td>0.08</td>
<td>-0.07</td>
<td>THI</td>
<td>0.11</td>
<td>-0.04</td>
<td>14</td>
<td>0.23</td>
<td>+0.10</td>
<td>CI14</td>
<td>0.47</td>
<td>+0.10</td>
<td>CI14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superficial depth</td>
<td>154</td>
<td>CI14</td>
<td>0.21</td>
<td>+0.06</td>
<td>THI</td>
<td>0.25</td>
<td>+0.08</td>
<td>14</td>
<td>0.24</td>
<td>+0.10</td>
<td>CI14</td>
<td>0.47</td>
<td>+0.10</td>
<td>CI14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fatty background and &lt;1.5 cm</td>
<td>148</td>
<td>CI14</td>
<td>0.03</td>
<td>-0.15</td>
<td>THI</td>
<td>0.52</td>
<td>+0.34</td>
<td>14</td>
<td>0.44</td>
<td>+0.28</td>
<td>CI10</td>
<td>0.68</td>
<td>+0.28</td>
<td>CI10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Δ is the average of the (order effect–adjusted) rank difference between the preceding and following. ΔLB, the lower bound of a symmetric 95% confidence interval for Δ. If it is negative, that is equivalent to no statistically significant difference between the 2 settings. If it is positive, that is equivalent to a statistically significant difference between the 2 settings. 14 indicates conventional imaging at 14 MHz.

**Table 3. Margin Assessment**

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Lesions, n</th>
<th>Ranked Best</th>
<th>Δ</th>
<th>ΔLB</th>
<th>Ranked Best</th>
<th>Δ</th>
<th>ΔLB</th>
<th>Ranked Best</th>
<th>Δ</th>
<th>ΔLB</th>
<th>Ranked Best</th>
<th>Δ</th>
<th>ΔLB</th>
<th>Ranked Best</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>413</td>
<td>CI10</td>
<td>0.002</td>
<td>-0.12</td>
<td>CI14</td>
<td>0.04</td>
<td>-0.07</td>
<td>14</td>
<td>0.68</td>
<td>+0.57</td>
<td>THI</td>
<td>0.43</td>
<td>+0.23</td>
<td>THI</td>
</tr>
<tr>
<td>Superficial and &lt;1.5 cm</td>
<td>130</td>
<td>CI14</td>
<td>0.39</td>
<td>+0.21</td>
<td>14</td>
<td>0.05</td>
<td>-0.11</td>
<td>CI10</td>
<td>0.43</td>
<td>+0.23</td>
<td>THI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not superficial and &lt;1.5 cm</td>
<td>210</td>
<td>CI10</td>
<td>0.02</td>
<td>-0.15</td>
<td>14</td>
<td>0.09</td>
<td>-0.07</td>
<td>CI14</td>
<td>0.66</td>
<td>+0.48</td>
<td>THI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not superficial and &gt;1.5 cm</td>
<td>49</td>
<td>CI10</td>
<td>0.35</td>
<td>+0.14</td>
<td>14</td>
<td>0.06</td>
<td>-0.17</td>
<td>CI14</td>
<td>0.47</td>
<td>+0.16</td>
<td>THI</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Δ is the average of the (order effect–adjusted) rank difference between the preceding and following. ΔLB is the lower bound of a symmetric 95% confidence interval for Δ. If it is negative, that is equivalent to no statistically significant difference between the 2 settings. If it is positive, that is equivalent to a statistically significant difference between the 2 settings. 14 indicates conventional imaging at 14 MHz.
**Image Quality**

In the overall evaluation and for each individual category (background, fatty or glandular; and depth, not superficial or superficial) in image quality assessment, CI10 was significantly better than conventional imaging, and THI was significantly worse than conventional imaging (Table 5 and Figures 1–4).

**Discussion**

Experience shows that frequently, sonographic apparatuses are not fully optimized, and even if technical modes play a substantial role in accurate sonographic imaging and interpretation, radiologists in daily practice do not make use of the many potentially helpful settings available for various situations. Knowledge of the different settings available and their appropriate use may improve the quality of the examination. In our daily practice, we routinely use the different settings available on our sonographic apparatus. We found it interesting to review and share our experience in this domain, with hopes that this may encourage radiologists to better explore all the potential advantages of the equipment at their disposal.

**Lesion Detection**

Low contrast between breast masses and surrounding fat tissue is known to limit their sonographic detection, which can be even more difficult in the case of small masses. Our study confirms that THI leads to improved visibility of breast masses, notably in cases of subtle hypoechoic lesions against a fatty background. In our practice, THI or CI14 is routinely used as the first step of breast sonography in a fatty background (because of the increased conspicuity of the lesion against a fatty background) before its full characterization or any anticipated interventional procedure (biopsy or needle localization). Tissue harmonic imaging and CI14 are also particularly useful in the detection of the lymph nodes (in an axillary or intramammary location), as previously mentioned. In a case of a glandular background, the contribution of THI is more limited because it does not significantly improve the visibility of a lesion, particularly in cases of small lesions (<1.5 cm).

Two different factors contribute to these results. First, as previously reported, the improved contrast resolution is a major player in such circumstances because the mass appears more hypoechoic, and the surrounding fatty tissue

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**Table 4. Echo Texture Assessment**

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Lesions, n</th>
<th>Ranked Best</th>
<th>Δ</th>
<th>ΔLB</th>
<th>Ranked 2nd</th>
<th>Δ</th>
<th>ΔLB</th>
<th>Ranked 3rd</th>
<th>Δ</th>
<th>ΔLB</th>
<th>Ranked Worst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>413</td>
<td>CI10</td>
<td>0.18</td>
<td>+0.10</td>
<td>14</td>
<td>0.24</td>
<td>+0.14</td>
<td>CI14</td>
<td>0.58</td>
<td>+0.48</td>
<td>THI</td>
</tr>
<tr>
<td>Cysts superficial</td>
<td>30</td>
<td>CI14</td>
<td>0.40</td>
<td>+0.01</td>
<td>14</td>
<td>0.06</td>
<td>-0.22</td>
<td>CI10</td>
<td>1.1</td>
<td>+0.74</td>
<td>THI</td>
</tr>
<tr>
<td>Cysts not superficial</td>
<td>61</td>
<td>CI10</td>
<td>0.14</td>
<td>-0.11</td>
<td>14</td>
<td>0.06</td>
<td>-0.19</td>
<td>CI14</td>
<td>0.48</td>
<td>+0.17</td>
<td>THI</td>
</tr>
</tbody>
</table>

Δ is the average of the (order effect–adjusted) rank difference between the preceding and following. ΔLB is the lower bound of a symmetric 95% confidence interval for Δ. If it is negative, that is equivalent to no statistically significant difference between the 2 settings. If it is positive, that is equivalent to a statistically significant difference between the 2 settings. 14 indicates conventional imaging at 14 MHz.

**Table 5. Acoustic Phenomena and Image Quality**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Lesions, n</th>
<th>Ranked Best</th>
<th>Δ</th>
<th>ΔLB</th>
<th>Ranked 2nd</th>
<th>Δ</th>
<th>ΔLB</th>
<th>Ranked 3rd</th>
<th>Δ</th>
<th>ΔLB</th>
<th>Ranked Worst</th>
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<tbody>
<tr>
<td>Acoustic shadowing</td>
<td>84</td>
<td>THI</td>
<td>0.51</td>
<td>+0.31</td>
<td>C14</td>
<td>0.54</td>
<td>+0.34</td>
<td>C10</td>
<td>0.36</td>
<td>+0.17</td>
<td>CI10</td>
</tr>
<tr>
<td>Acoustic enhancement</td>
<td>135</td>
<td>THI</td>
<td>0.51</td>
<td>-0.04</td>
<td>C14</td>
<td>0.29</td>
<td>+0.18</td>
<td>C14</td>
<td>0.30</td>
<td>+0.20</td>
<td>C10</td>
</tr>
<tr>
<td>Image quality</td>
<td>413</td>
<td>CI10</td>
<td>0.46</td>
<td>+0.37</td>
<td>14</td>
<td>0.014</td>
<td>-0.07</td>
<td>C14</td>
<td>0.81</td>
<td>+0.71</td>
<td>THI</td>
</tr>
</tbody>
</table>

Δ is the average of the (order effect–adjusted) rank difference between the preceding and following. ΔLB is the lower bound of a symmetric 95% confidence interval for Δ. If it is negative, that is equivalent to no statistically significant difference between the 2 settings. If it is positive, that is equivalent to a statistically significant difference between the 2 settings. 14 indicates conventional imaging at 14 MHz.
appears less dark. Second, the reinforced posterior shadowing with THI is particularly helpful in real-time examination. This allows the radiologist or sonographer to first detect a lesion using these acoustic differences, thus more easily disclosing the underlying mass.

In such circumstances (lesion detection), CI plays the same role as THI. In addition, in cases of superficially located lesions, CI was the highest ranked for lesion detection. Interestingly, CI provided quite different results than CI4 in terms of lesion visibility. The contribution in lesion detection of frequency compounding at 10 MHz was limited in all situations. This is likely due to the higher frequency used and the stronger posterior acoustic phenomena noted with CI14.

**Lesion Characterization**

Once a lesion is detected, the next step involves its characterization with regard to the assessment of its shape, orientation, margins, echo texture, and posterior acoustic phenomena, following the sonographic lexicon for American College of Radiology Breast Imaging Reporting and Data System (BI-RADS) assessment. On one hand, we intuitively assumed that the assessment of the shape and the orientation of a mass are features that do not depend on the type of setting used. On the other hand, we thought that the determination of the margin characteristics or echo texture of the lesion, which might be limited in some circumstances, could benefit from specific settings. Margin evaluation is one of the more discriminating features for differentiating benign from malignant solid masses because it meets the criteria of frequency, reliability, and interobserver agreement. On the basis of our case material, compound imaging improved margins analysis in 2 different scenarios: in the case of a small (<1.5-cm) lesion superficially located and in the case of a large (≥1.5-cm) lesion not superficially located. Interestingly, THI was limited in margin assessments. In our opinion, this might be a consequence of the limited spatial resolution (in comparison with frequency compounding) noted with THI. The spatial resolution depends on axial resolution (along the sonographic image line) and lateral resolution (perpendicular to the image line). Tissue harmonic imaging usually improves lateral resolution while reducing axial resolution. Results vary between imaging platforms but follow a common trend of loss of spatial resolution with THI. This is probably reinforced by the THI technology (frequency filtering) used on our machine. The narrowed bandpass associated with filters results in limited axial resolution, particularly at high frequencies. Other technologies such as pulse inversion/phase cancellation and coded harmonics, with no filtering technique and with broad bandwidths, might diminish such limitations, particularly at high frequencies.

The best assessment of the echo texture was achieved with CI. We think that any type of compounding (spatial or frequency) is helpful in decreasing speckle and other sources of noise, thereby inducing a better definition of the internal structure within masses, particularly in the recognition of cystic components.

Classically, THI has been reported to enhance the cystic components in reducing artifactual internal echoes. This was not noted in our work because our results showed a limited impact of THI on cystic component analysis. Once again, the diminished spatial resolution associated with limited image quality with THI might explain these findings. This is probably reinforced in cases of small and deeply located lesions because THI at high frequencies shows limitations. However, similarly to Berg, who found spatial compounding pertinent in evaluating clustered microcysts, frequency compounding appeared to be a helpful tool in echo texture assessment in cases of cystic lesions.

**Image Quality**

In our study, the best image quality was achieved with CI, as opposed to tissue harmonic images, which appeared coarse and noisy, compared with conventional imaging. A “speckle” artifact degrades the images and reduces the ability to detect details. Frequency compound sonography obtains scans from several frequencies, producing different speckle artifact patterns in each frame. This averaging of frames reduces the speckle and grainy appearance observed on conventional sonography, resulting in improved image quality. Improved image quality with spatial compounding imaging techniques has been also noted in other studies.
Tissue Harmonic, Compound, and Conventional Breast Imaging

Our study had several limitations. First, the study was limited to only 1 type of sonography machine. On one hand, our results cannot be generalized to another sonographic apparatus because different machines use different techniques to generate settings. On the other hand, previous studies have shown “remarkable differences” in terms of spatial resolution between 2 different types of THI on 2 different types of equipment. Therefore, we thought that mixing different apparatuses, and therefore different techniques, might not have been clinically valid. Second, we did not evaluate spatial compounding, which has been recently assessed in breast sonography. Third, interpretation of preselected static images introduced a considerable bias, whereas real-time evaluation would have provided more information because it reflects the normal practice in breast sonography. In addition, retrospective review does not reflect actual everyday practice because real-time scanning allows the sonographer to estimate which setting is the most appropriate to use in each specific clinical situation. Specific parameters, such as posterior shadowing used to detect a subtle hypoechoic mass against a fatty background, can be quite conspicuous on real-time evaluation yet not objectively identified on static images. Finally, 2 readers performed reading in consensus. Thus, the interobserver variability was not assessed. However, studies have shown previously good to excellent interobserver variability in the different criteria evaluated, such as echo texture and margin assessment.

In summary, our study results showed that THI improved breast mass detection particularly against a fatty background. Frequency compounding improved lesion echo texture analysis but had a more limited impact on margin analysis, the more discriminating feature for differentiating benign from malignant lesions. No single setting in isolation can provide the necessary optimized information for lesion detection and characterization. As such, breast abnormality evaluation is best performed with the different available sonographic apparatus settings, particularly in scenarios known to be difficult. Although our study was limited to a single sonographic apparatus, it highlights the necessity of understanding as well as the use and benefits of different modes available on most commercially available sonography machines.

References


