The effect of pre-compression on breast elastography

Poster No.: C-0885
Congress: ECR 2012
Type: Scientific Paper
Authors: R. G. Barr¹, J. R. Grajo²; ¹Youngstown, OH/US, ²Tampa, FL/US
Keywords: Breast, Elastography, Ultrasound, Neoplasia
DOI: 10.1594/ecr2012/C-0885

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method ist strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.myESR.org
Purpose

To determine the effect of pre-compression on ultrasound elastography images and propose a method to semi-quantitate the amount of pre-compression

Methods and Materials

Ten patients scheduled for breast ultrasound with elastography were evaluated with graded compression on the breast lesion. Patients were evaluated on either or both a S2000 research unit with strain and shear wave capabilities (Siemens Ultrasound, Mountain View, Ca) or an Aixplorer (Supersonic Imagine (SSI), Aix-en-Provence, France) with quantification turned on (not FDA approved for quantification/research unit in USA).

For the S2000 system, strain imaging was performed with both the 14L5 and the 9L4 probes. The shear wave imaging was performed with the 9L4 using ARFI technology (1). The system was modified to save raw shearwave data for analysis off line. For the SSI system, a SL15-4 probe was used. Determination of the breast tissue type being evaluated was based on the B-mode appearance (fat, fibroglandular tissue, lipoma) or biopsy confirmation (fibroadenoma, fat necrosis, malignancy). Tissue biopsy was performed with a 12g Celero (Hologic, Indianapolis, IN) biopsy gun.

Graded compression was applied by varying the amount of pre-compression from minimal to marked. An estimation of the pre-compression applied was calculated as follows. A structure in the far field was chosen (e.g. rib, Cooper's ligament, or pectoralis muscle), which was present in the whole series of images. The distance of the structure was documented at each level of compression. The ratio of the distance with compression to the distance of the structure with the least amount of pre-compression was calculated (Figure 1) and expressed as the percentage of compression as related to least compressed image. The image with minimal compression was obtained by lifting the ultrasound probe and watching the selected object in the far field. The probe was lifted until the object no longer moved deeper in the image and probe contact was maintained. At each graded pre-compression image, the speed of the shear wave (Vs) was obtained. Plots of Vs to the ratio of compression were performed. Images obtained with both strain and shearwave were obtained at varying levels of pre-compression and compared. For the purposes of this paper, "% compression" refers to "total % compression from body surface."

Three sonographers with different amounts of elastography training (no experience, 1 year experience or 10 years experience) performed a reproducibility study. Three
patients selected each had an easily detectible fat lobule. Each sonographer was asked to measure the Vs of the central portion of the fat lobule using the method of applying minimal pre-compression ten times. Between each measurement the ultrasound probe was removed from the breast. The sonographer was also asked to repeat the measurements ten times with 25% pre-compression. Variability within each sonographer's measurements as well as the difference between sonographers means were obtained and compared. To measure the reproducibility of each sonographer's measurements, the root-mean-square coefficient of variation (RMS CV, expressed as a percentage) was determined from all available data according to the method of Gluer et. al. (2), whereas the coefficient of variation (CV) for each subject with repeated measures is the ratio of the standard deviation to the mean and is expressed as a percentage.

**Images for this section:**

![Fig. 1](image-url)

**Fig. 1:** To calculate the % compression, an object in the far field of view is identified (e.g. rib, Cooper's Ligament). The ultrasound probe is lifted and the object will move deeper in the image. The probe is lifted until the object is as deep in the image as possible while still maintaining probe contact. In Figure A, the rib is at 4 cm depth when minimal pre-compression is applied. In Figure B, where some pre-compression is applied, the rib is at 3 cm depth. The % compression using our method is 1- (3cm/4cm) = 25%.
Results

For all tissue types, the speed of the shear wave increases with added pre-compression in a non-linear fashion. Results are presented in Figure 2. For "soft" tissues such as fat or fibroglandular tissue, a 10% increase in pre-compression approximately doubles the Vs. Soft tissues such as fat can have the same elasticity properties of cancer tissue with high pre-compression. Similar results were obtained for a tissue type with both techniques to measure Vs (ARFI, Siemens Ultrasound and SWE, Supersonic Imagine technique). The effects of pre-compression can also be identified by looking at the changes of the shear wave progression (Figure 3). As pre-compression is increased, the shear waves arrive faster at a given point and have decreased amplitude.

Figure 4 is a diagram summarizing the Vs of the different tissue types in breast at various amounts of pre-compression, which we used for the results and discussion below. The amount of pre-compression is classified into 4 categories: Zone A (minimal pre-compression 0-10%), Zone B (mild pre-compression 10-25%), Zone C (moderate pre-compression 25-40%), and Zone D (marked pre-compression > 40%).

How does pre-compression affect strain elastography images?

In strain elastography, images are based on the relative stiffness of the lesions within an image so that it is qualitative but not quantitative. The imaging scale used is relative and based on tissues within the image plane. In the case where both soft tissues (fat, fibroglandular tissue) and a hard lesion (malignancy) are present in Zones A, B, and C, the difference in elasticity between the soft tissues and malignant lesions are adequate to generate an accurate elastogram. However, in Zone D the elasticity of both soft tissues and malignancies are similar. Hence, the elastogram is not diagnostic and only represents noise.

However, in the case where the area of interest contains only "soft" tissues (fat, fibroglandular, soft fibroadenoma, fibrocystic change), the results are different. In Zone A, the elasticity differences between the tissues allows for a diagnostic elastogram. In Zone B, the elastogram is borderline for diagnostic value with some frames of good diagnostic quality and some with poor diagnostic value. Based on the author's experience, this appears to depend if the frame was taken in a compression or release phase of the cycle. This may be due to the increased pre-compression on the compression phase of the cycle. In Zones C and D, the elasticity properties of the soft tissues are very similar and the elastogram is mostly noise and non-diagnostic. Figure 5 demonstrates the effect of different amounts of pre-compression on the strain elastogram in a patient with an epidermoid cyst.
How does pre-compression affect shear wave elastography images?

As one applies pre-compression, the speed of the shear wave (Vs) in the tissue increases, regardless if the tissue is "soft" or "hard". In general, for tissues present in breast, the rate of change in Vs with increasing pre-compression is greater with soft tissues and less with hard tissues. Thus the speed of the shear wave (Vs) or Young's modulus (kPa) increases in all tissues as the amount of pre-compression is applied. At 10% pre-compression, the speed of most "soft" tissues approximately doubles. With amounts of pre-compression in Zones A and B, benign lesion Vs will remain within the range suggestive of benign lesions. However, in Zones C and D, a benign lesion may have a Vs suggestive of a malignant lesion. A clinical example is provided in Figure 6. In this case, a complicated cyst can be made to have Vs or kPa value suggestive of a malignancy with sufficient pre-compression. With malignant lesions, the Vs remains above the threshold for a malignant lesion regardless of the amount of pre-compression. However, in some cases a malignant lesion may appear as a "soft" lesion with a low Vs or kPa value and a "ring" of high Vs or kPa surrounding the lesion is noted (3). In these cases, the high Vs ring is used to diagnosis the lesion as suspicious for being malignant. A similar effect with pre-compression is found in these cases (Figure 7). This situation presents two issues; (1) the amount of pre-compression and (2) the apparent low Vs or kPa of the cancer itself. In this paper, we address the issue of pre-compression and how to obtain consistent accurate results. However, with this technique, many cancers will be affected by the second issue, the apparent low Vs of the cancer. This has been discussed elsewhere (3).

Sonographer reproducibility

The reproducibility of Vs in the systems used in this study are +/- 10% (4, 5). In addition, the exact same fat tissue varied slightly as the probe was removed from the breast between each measurement. Therefore, our goal was to develop a technique which had a variability of approximately 10%. As demonstrated in Figure 2, by applying pre-compression, the clinical range of measurements for fat can vary by applying pre-compression by a factor of 10, ranging from 1.0 m/s to 10 m/s. For fat within the breast, a 10% change with the least amount of compression utilized would range from 0.9 to 1.1 m/s. Hence, a 10% variability of measurement would not change clinical results. Based on the graphs in Figure 2, it would require an approximately 100% variability of measurement to change clinical results. As shown in Table 1, results of Vs were reproducible at both 0% and 25% pre-compression settings, with the majority of coefficient of variations for each case below 10%. The RMS-CVs for each sonographer were between 6 and 10%.
Fig. 2: Shear wave speed of various tissues that occur in breast with various amounts of pre-compression applied. The "% compression refers to the total % compression from body surface" as discussed in the text. As pre-compression is applied, the shear wave speed increases in a non-linear fashion. At approximately 40% compression, all tissues have a shear wave velocity of approximately 10 m/s. Softer tissues (fat, fibroglandular tissue, fibroadenomas) have a greater rate of change in shear wave velocity than harder tissues (cancers).
**Fig. 3:** Graphs showing the shear waves at different distances from the push pulse for fat in a normal breast at different amounts of pre-compression. The reference graph is 0% pre-compression, Compression 1 graph is approximately 10% pre-compression, Compression 2 graph is approximately 25% compression and Compression 3 graph is approximately 40% compression. As pre-compression is increased, the shear wave peaks occur at an earlier time (faster Vs) and the signal is attenuated.
Fig. 4: Diagram demonstrating the average changes of Vs in tissue types that occur in breast tissue. We identify 4 regions of pre-compression that explain clinical results of elastography. In Zone A, 0-10% pre-compression using technique at measured pre-compression, clinical results using both strain and SWE are not affected. In Zone B, at 10-25% pre-compression strain images with only benign pathology begin to degrade, while SWE measurements increase but in general will not change from Vs suggestive of a benign lesion to a value suggestive of a malignant lesion. In Zone C, 25-40% and D, >40% strain images with benign pathology become only noise as the elastic properties of all the tissue become too similar to distinguish. If a malignant lesion is present, strain imaging will be accurate in Zones A, B, and C as the elastic properties of normal breast tissue remains different enough from the malignancy to provide accurate results. Benign lesions in zones C and D on shear wave will have Vs (kPa) values suggestive of a malignant lesion. It is recommended that all clinical images be obtained in Zone A.
Fig. 5: The effect of pre-compression on strain imaging of an epidermoid cyst is demonstrated in this figure. In the bottom image, the elastogram is obtained with minimal pre-compression. The epidermoid cyst is seen as a "hard" (black) lesion and is seen on all frames during the exam. In the middle image, a mild amount of pre-compression is applied. The elastogram has frames which are good quality but others which are of poor quality and non-diagnostic. With significant pre-compression all frames are non-diagnostic and the images are just noise as all the tissues have similar elastic properties. The red arrows point to a rib, which can be used to determine the amount of pre-compression applied.
**Fig. 6:** The effects of pre-compression with shearwave imaging are demonstrated in this image. The lesion is a benign cyst. As pre-compression is increased, the cyst and the tissues surrounding the cyst have increased Vs, which can be easily identified by the change in the color coding of the image. The yellow arrows point to a rib, which can be used to determine the amount of pre-compression. This image demonstrates why shearwave images should be obtained with minimal pre-compression.

**Fig. 7:** The effect of pre-compression on an invasive ductal cancer is similar to the cyst in Figure 6. With minimal pre-compression, the invasive ductal cancer is poorly colored as the shearwave does not generate. As pre-compression is applied, the Vs surrounding the tissue increases. The arrows point to a Cooper’s ligament that can be used to determine the amount of pre-compression.
<table>
<thead>
<tr>
<th></th>
<th>0% pre-compression</th>
<th>25% pre-compression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sonographer 1</td>
<td>Mean(SD)</td>
<td>Mean(SD)</td>
</tr>
<tr>
<td>Case 1</td>
<td>1.188(0.068)</td>
<td>2.485(0.233)</td>
</tr>
<tr>
<td>Case 2</td>
<td>0.907(0.120)</td>
<td>3.506(0.282)</td>
</tr>
<tr>
<td>Case 3</td>
<td>1.141(0.109)</td>
<td>3.153(0.287)</td>
</tr>
<tr>
<td>Sonographer 2</td>
<td>CV(%)</td>
<td>CV(%)</td>
</tr>
<tr>
<td>Case 1</td>
<td>5.75</td>
<td>9.38</td>
</tr>
<tr>
<td>Case 2</td>
<td>13.21</td>
<td>8.05</td>
</tr>
<tr>
<td>Case 3</td>
<td>9.52</td>
<td>9.10</td>
</tr>
<tr>
<td>Sonographer 3</td>
<td>RMS CV(%)</td>
<td>RMS CV(%)</td>
</tr>
<tr>
<td>Case 1</td>
<td>9.97</td>
<td>8.86</td>
</tr>
<tr>
<td>Case 2</td>
<td>7.90</td>
<td>8.05</td>
</tr>
<tr>
<td>Case 3</td>
<td>6.28</td>
<td>6.04</td>
</tr>
</tbody>
</table>

**Table 1:** Reproducibility of elastography measurements, measured by RMS CV(%)
Conclusion

In this paper, we quantify the effects of pre-compression on both strain and shear wave elastography using both shear wave measurements as well as images from clinical cases. The effects of pre-compression are marked in the breast and can easily affect the predictive value (benign vs malignant). We have developed a clinically useful method of determining semi-quantitative value of the amount of pre-compression applied. This method is easy to perform, does not require additional equipment or calibration, and can be used with any system performing strain or shear wave elastography. Although this method is semi-quantitative, it can be used to obtain results with a small range of pre-compression, which should not affect clinical results.

Our results confirm that pre-compression can severely affect results for both strain and SWE in breast imaging. The acquisition of strain and SWE images with minimal pre-compression is required to have accurate results. We have categorized pre-compression into 4 zones. In Zone A, 0-10% pre-compression using the technique recommended to measure pre-compression, clinical results using both strain and SWE are not affected. In Zone B, 10-25% strain images with only benign pathology begin to degrade, while SWE measurements increase but in general will not change values that are suggestive of a benign lesion to values of Vs (kPa) suggestive of a malignant lesion. In Zone C, 25-40% and D, >40% strain images with benign pathology become only noise as the elastic properties of all the tissue become too similar to distinguish, while benign lesions in Zones C and D will have Vs (kPa) values within the range of malignant lesions. It is recommended that all clinical breast images be obtained in Zone A.

References


**Personal Information**

Dr. Barr is a Professor of Radiology at Northeast Ohio Medical University in Rootstown, OH.

Dr. Grajo is a radiology resident (PGY-3) at University of South Florida in Tampa, FL.

Dr. Barr has received equipment grants from Siemens Ultrasound, Philips Ultrasound and SuperSonic Imagine.

Dr. Barr is on the advisory boards of Siemens Ultrasound and Philips Ultrasound.

Dr. Barr is a lecturer for Philips Ultrasound and Siemens Ultrasound.