Variable Breast Conditions

Comparison of Conventional and Real-time Compound Ultrasonography

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Objectives. To illustrate and compare the appearances of variable breast conditions by conventional and real-time spatial compound images. ***Methods.*** Cases illustrative of a broad range of breast conditions were collected. Each image pair consisted of conventional and real-time compound images with a stationary probe to maintain an identical projection. ***Results.*** The various breast conditions, including normal anatomic structures and abnormal lesions, were evaluated and compared by conventional and real-time compound images. The real-time compound images revealed more realistic and clear images with reduced artifacts. ***Conclusions.*** Real-time compound images are superior to conventional images of normal and abnormal breast conditions. Real-time compound imaging is a good technique for evaluating the breast state. ***Key words:*** breast ultrasonography; ultrasonography; ultrasound technology.

For the last 3 decades, mammography has been the basic imaging modality for the evaluation of patients with breast abnormalities, and it is still the most widespread and important method for screening of breast cancer. However, differentiation of benign from malignant masses on mammography may still be very difficult. In response to the diagnostic deficiencies of mammography, ultrasonography has emerged as the most important adjunct method to mammography.[1] Moreover, the development of high-resolution transducers is well suited to depicting the fine anatomic structures of the breast. Recently, to overcome the inherent artifacts of conventional ultrasonography, which compromise image quality, real-time compound imaging has been developed.

The intent of this presentation is to illustrate and compare conventional and compound images of various breast conditions.

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Materials and Methods

This study was performed with patients in the Ultrasound Division of the Department of Radiology, Severance Hospital (Seoul, South Korea). The study, conducted between May and December 2001, was performed with an HDI 5000 SonoCT system and a broad-bandwidth L12-5 linear scan head (Philips Medical Systems, Bothell, WA). Various breast conditions were scanned by conventional imaging first and then by compound imaging with the same parameters, including gain, magnification, depth, focus, and tissue compression. Our ultrasound equipment can operate in 2 compound image modes: target and survey. The survey mode produces 3 coplanar images and allows rapid scanning, and the target mode produces 9 images. We used compound images in the target mode in all cases for maximizing the compound nature.

Results

Representative examples of normal and abnormal breast conditions are presented in Figures 1–19 to show comparisons between conventional and compound images.

Discussion

The role of ultrasonography in breast imaging has increased over the years. In the past, ultrasonography of the breast was limited to differentiation of cysts from solid masses.[2–4] Recently, the roles of ultrasonography have expanded because of the technical development of the ultrasound equipment.

Ultrasonographic techniques such as harmonic and compounding imaging have recently been introduced. Tissue harmonic imaging is an increasingly used ultrasonographic technique. This technique has 2 modes, tissue harmonic imaging and pulse inversion imaging. In tissue harmonic imaging, the ultrasound beam transmits at 1 frequency and receives at twice that frequency, that is, the second harmonic frequency. High-pass or narrow-bandpass filtering is applied to the received echoes to filter out the fundamental echo components. The resolution and sensitivity are thus limited by a fundamental compromise in the frequency-filtering approach.[5] Pulse inversion harmonic imaging transmits multiple identical pulses with reversed polarity. When the echoes from the transmitted pulses are added, the linear components of the echoes cancel each other, whereas the nonlinear components are amplified. This results in superior contrast and spatial resolution.[6]

Figure 1. Cooper ligament within an underlying normal breast structure. **A**, Conventional image showing posterior acoustic shadowing due to the Cooper ligament. **B**, Compound image showing no definite posterior acoustic shadowing due to the Cooper ligament. Suppression of the artifact is achieved by obtaining multiple coplanar tomographic images from different viewing angles and combining them into a single compound image at real-time frame rates.

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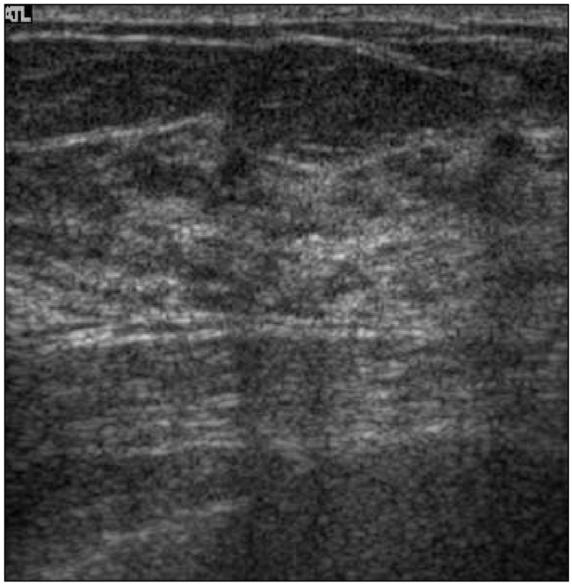

B

A newer technique, real-time compound imaging, is now in use. The practical implementation of this technology has only recently been made possible by the substantial computational power of modern, all-digital ultrasound systems. Real-time compound imaging starts by acquisition of multiple frames from different viewing angles; the overlapping frames are then combined to form a real-time compound image on the display.[7] Compound images can be obtained by a conventional imager with 2 modifications. First, the ultrasound beams are steered "off axis" from the 90° beams used in conventional imaging. Second, the image processor must be pro-

Figure 2. Normal subareolar complex. **A**, Conventional image showing extensive tissue shadowing caused by abundant fibrous tissue and multiple beam reflections by many major ductal walls. **B**, Compound image showing improved resolution of the ductal wall and lumen with decreased shadowing.

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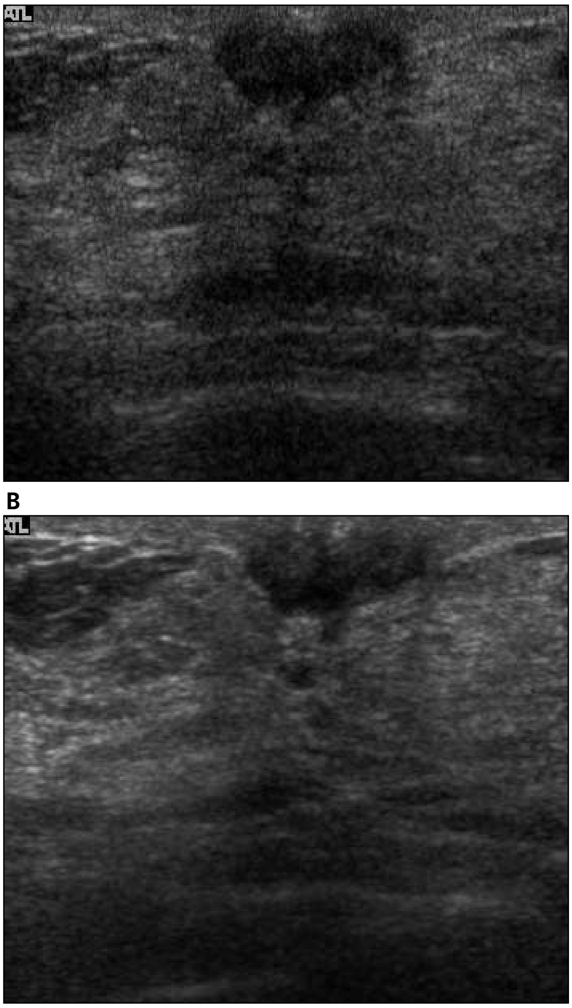

Figure 3. Axillary vessel. **A**, Conventional image showing a slightly indistinct margin of the axillary artery and questionable acoustic echoes in the midportion of the vessel. **B**, Compound image showing improved delineation of boundaries and clear internal echoes with clutter suppression.

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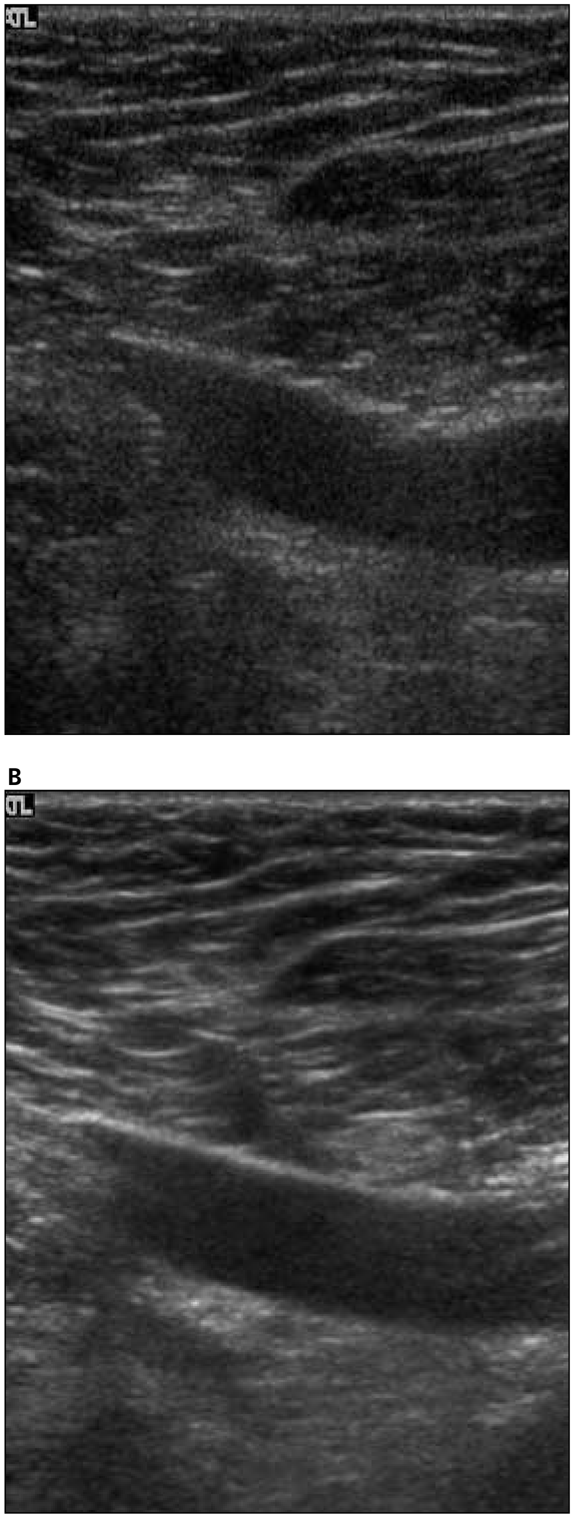


grammed to accurately render the steered frames into the appropriate display configuration and then to combine them through frame averaging. This, however, introduces a persistent effect, with the potential for image blurring if the transducer or the target moves too rapidly. In general, the more frames in the acquisition sequence, the greater the improvement in image quality and the greater the potential for motion blurring. For this method, real-time compound imaging overcomes the inherent artifacts of ultrasonography.

Ultrasonographic images are degraded by coherent wave interference, known as speckling, which gives a granular appearance to an otherwise homogeneous region of tissue.[8] Reduced speckling contributes to better definition of boundaries and better detection of low-contrast regions or hyperechoic microstructures such as microcalcifications.[9] Clutter, which consists of spurious echoes that can often be visualized

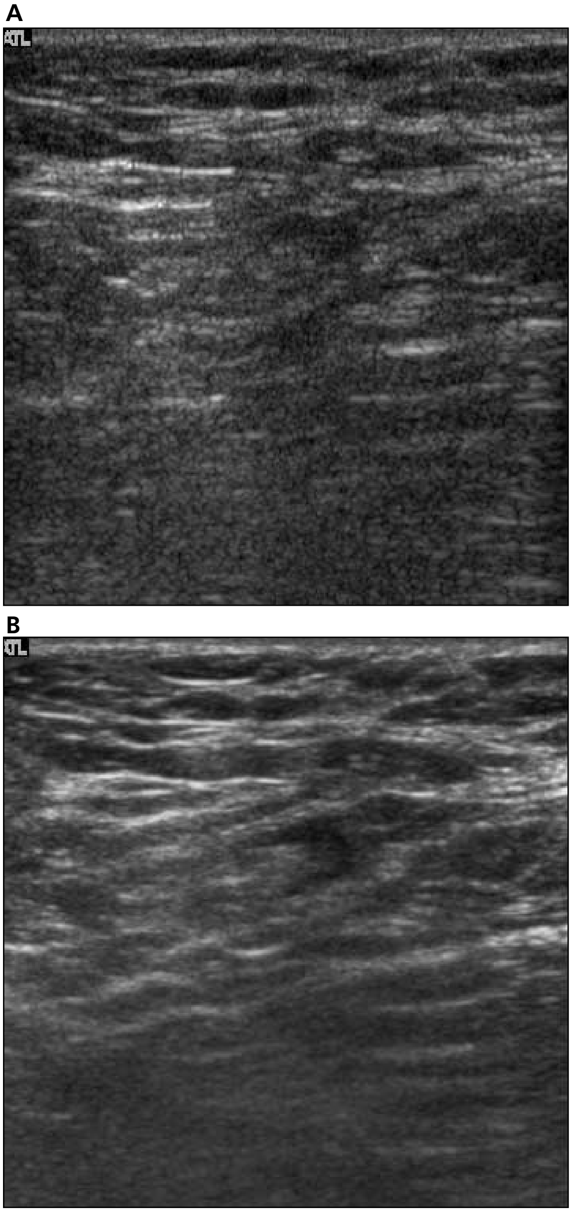


Figure 4. Reactive hyperplasia of an axillary lymph node. **A**, Conventional image showing unclear delineation of the axillary lymph node. **B**, Compound image showing more discrete delineation of the node.

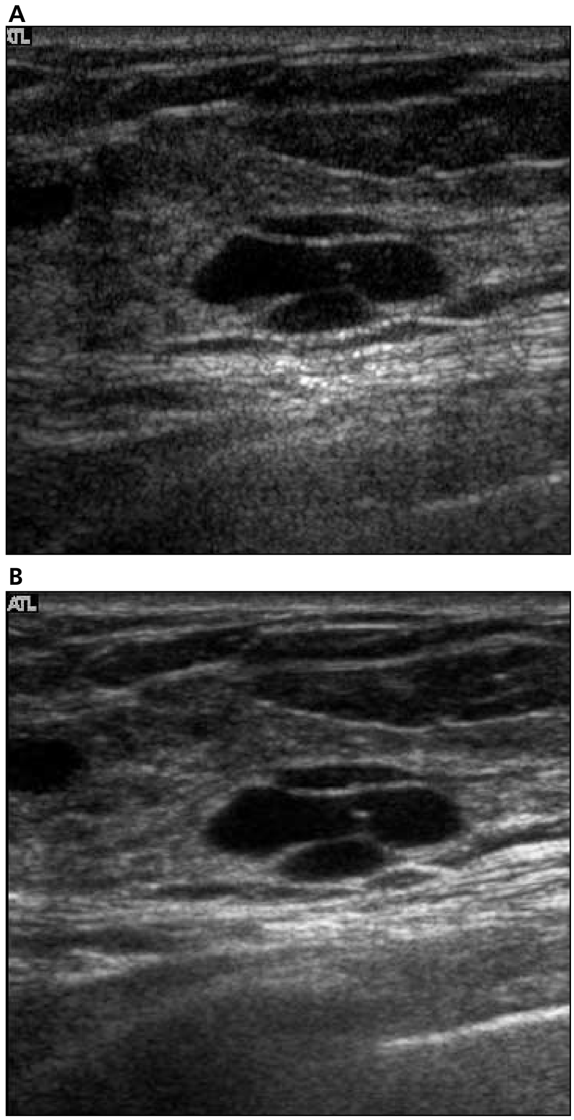


Figure 5. Septated cyst in a 49-year-old asymptomatic woman who received hormone replacement therapy for 2 years. **A**, Conventional image showing spurious echoes within the cyst due to acoustic clutter. **B**, Compound image showing a clear cystic nature within the mass with a reduced clutter artifact.

within a breast cyst and that may lead to concern as to whether a cyst is simple or complex, arises from side lobes or grating lobes or because of multipath reverberation. In real-time compound imaging, scanning from different angles produces different artifact patterns, and the averaging of these independent frames suppresses the artifacts and reinforces real structures. Therefore, real-time spatial compound imaging has improved margin definition, reduction of clutter, and visualization of microcalcifications.[9]

Real-time spatial compound imaging was first reported in the 1980s,[10,11] but renewed interest arose in the 1990s. The introduction of real-time spatial compound imaging on the HDI 5000 ultrasound system has allowed physicians and sonographers to begin evaluating compound imaging in a variety of medical applications, pri-

Figure 6. Fibroadenoma in a 44-year-old woman who underwent screening ultrasonography. Her mammographic findings were normal, with a heterogeneous dense breast pattern. This lesion was confirmed by 14-gauge core needle biopsy. **A**, Conventional image showing mild posterior acoustic enhancement. **B**, Compound image showing improved delineation of the margin and better appreciation of the internal architecture. Posterior acoustic enhancement is somewhat decreased.

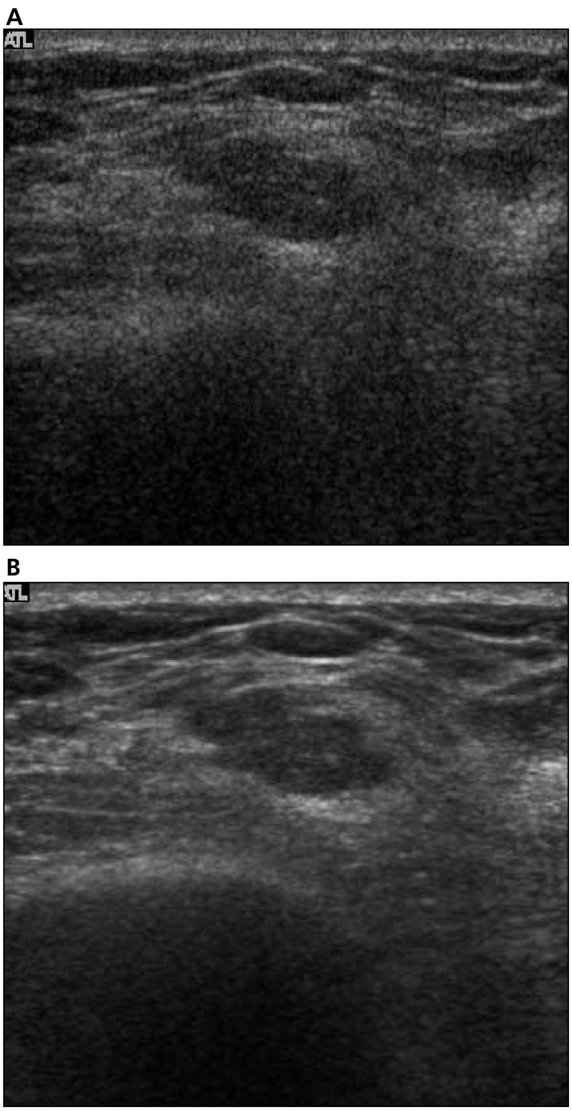
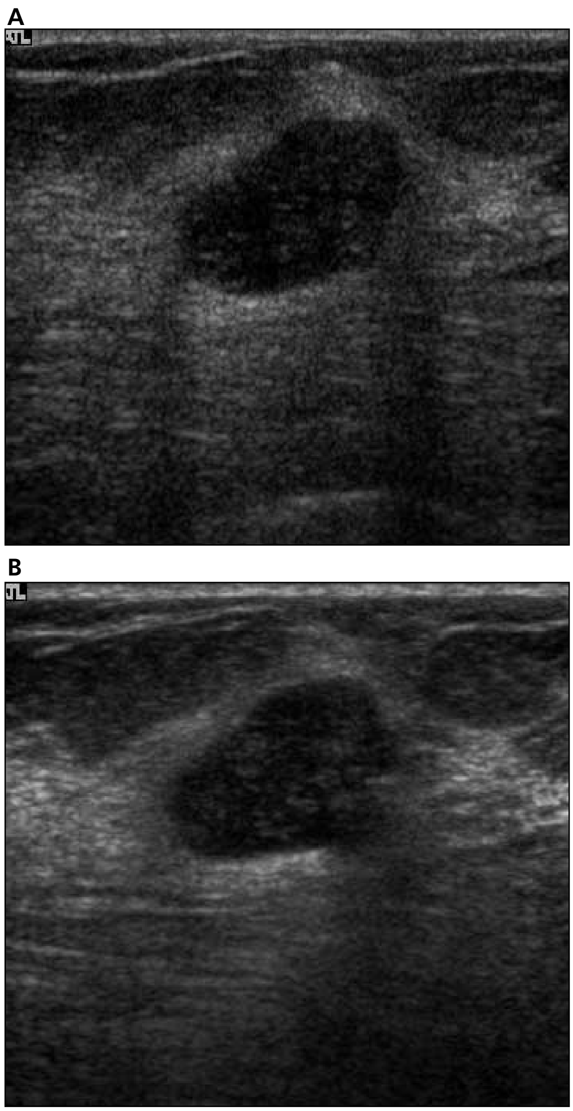


Figure 7. Phyllodes tumor in a 45-year-old woman who had a palpable mass for 3 months. This lesion was confirmed as a fibroadenoma first by 14-gauge core needle biopsy. Excision resulted in the benign phyllodes tumor. **A**, Conventional image showing lateral shadowing and posterior acoustic enhancement. **B**, Compound image showing decreased lateral shadowing and posterior acoustic enhancement.



marily in breast,[7,12,13] vascular,[7] and musculoskeletal imaging.[7,14]

The 2 above-mentioned techniques (tissue harmonic imaging and real-time compound imaging) showed improved lesion characterization compared with conventional ultrasonography.[9,15]

Our real-time compound imaging equipment enables clinicians to acquire up to 9 times more information than they can with the orthogonal beams used in conventional ultrasonography, without any unusual manipulation of the scan head and without sacrificing frame rates. The real-time spatial compound images can improve spatial and contrast resolution, characterize the margins of a nodule better, and enhance the delineation of internal architecture and microcalcifications, resulting in a bet-

Figure 8. Fat necrosis in a 47-year-old woman who had a palpable mass for 5 months. Her history included a partial mastectomy due to breast cancer 4 years previously. This lesion was confirmed by 14-gauge core needle biopsy. **A**, Conventional image showing unclear delineation of the margin and an internal echo texture in the mass. **B**, Compound image showing more discrete delineation of the margin and improved soft tissue contrast of the mass. Breast tissue is complex and of intrinsically lower acoustic contrast than that of other bodies. Spatial compound imaging overcomes this drawback.

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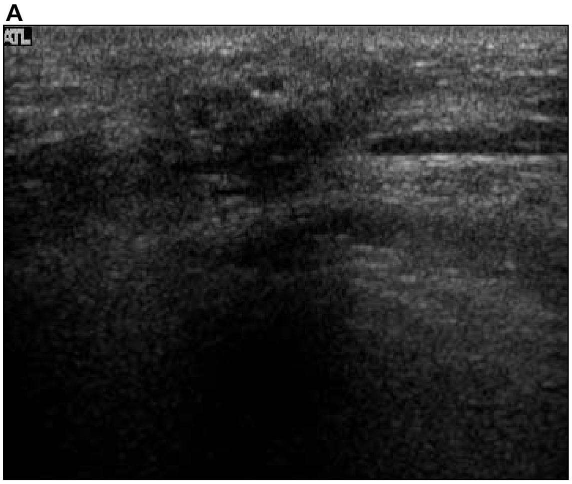

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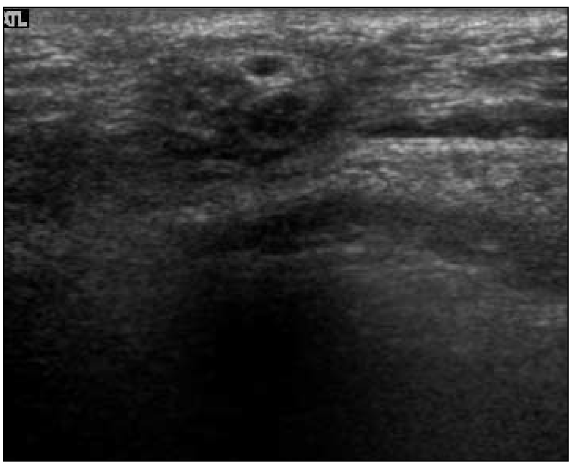
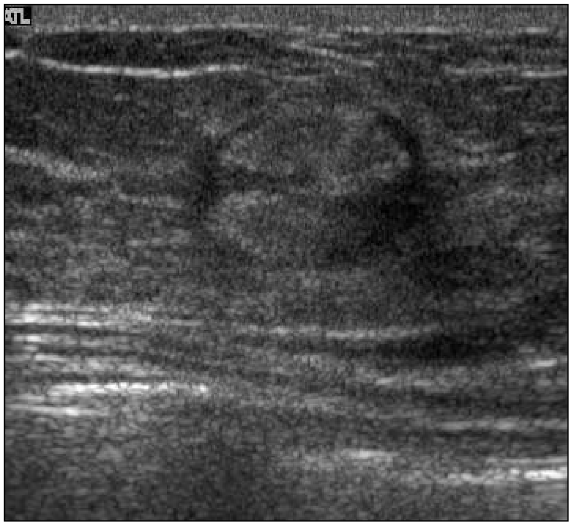


Figure 9. Stromal fibrosis in a 19-year-old woman who had a palpable mass for 1 month. This lesion was confirmed by 14-gauge core needle biopsy. **A**, Conventional image showing indistinct soft tissue contrast and an internal echo texture in the mass. **B**, Compound image showing more discrete soft tissue contrast and delineation of the margin of the mass.

A



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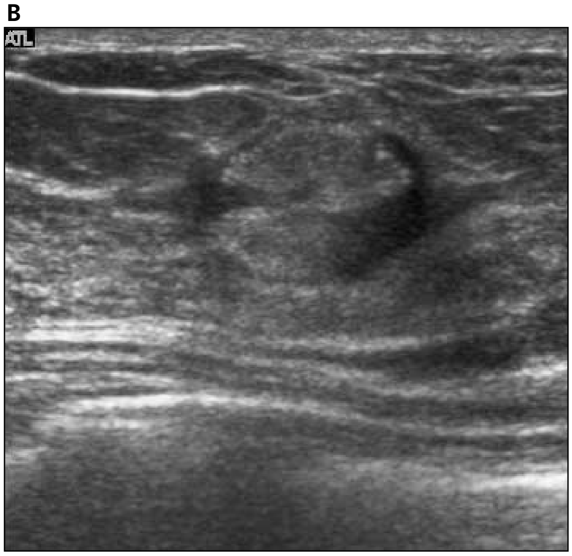


ter differential diagnosis. The potential limitation of real-time compound imaging is diminished acoustic shadowing, so a combined approach of high-resolution conventional ultrasonography with concurrent real-time spatial compound imaging is needed.[7]

In conclusion, real-time compound images are superior to conventional images of normal and abnormal breast conditions. Although the images have decreased acoustic shadowing, real-time compound imaging is a good technique for evaluating the breast state.

Figure 10. Galactocele in a 27-year-old woman who had a palpable mass for 3 months. Breast-feeding was done for 3 months. This lesion was confirmed by 14-gauge core needle biopsy. **A**, Conventional image showing spurious echoes and an indistinct internal echo texture within the cystic mass. **B**, Compound image showing a more distinct margin and internal echo texture with a reduced clutter artifact.

A

B

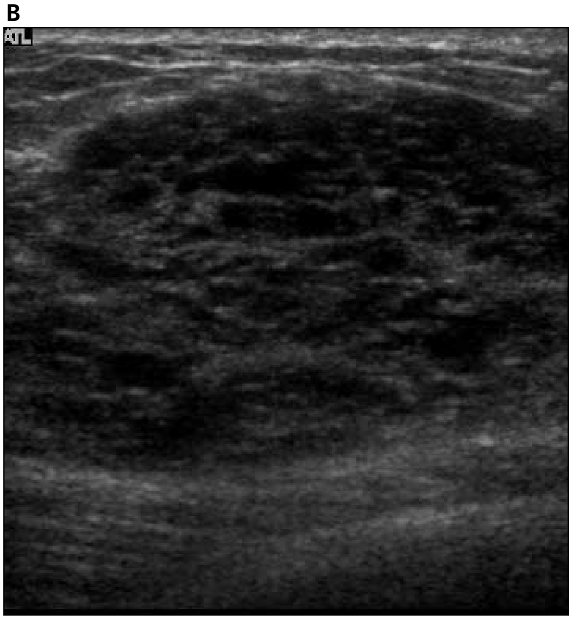
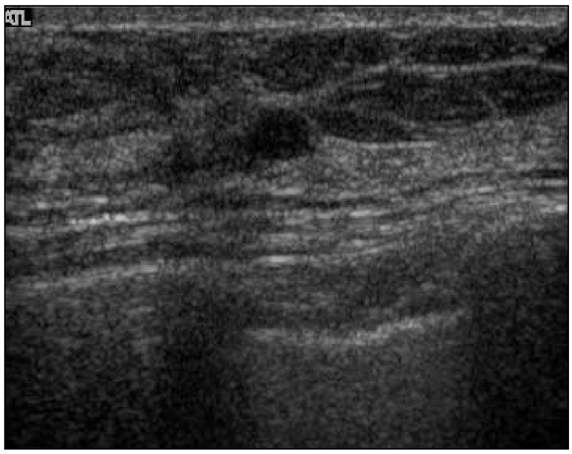


Figure 11. Adenosis in a 50-year-old asymptomatic woman. This lesion was confirmed by 14-gauge core needle biopsy. **A**, Conventional image showing a slightly indistinct margin of the mass. **B**, Compound image showing a more distinct margin and improved soft tissue contrast within the mass.

A



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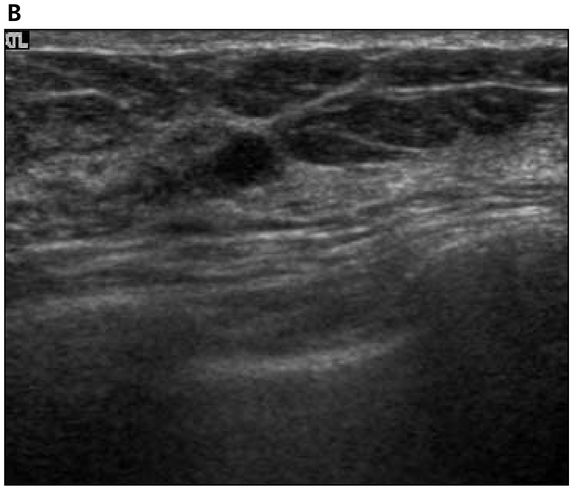


Figure 12. Papilloma in a 50-year-old woman who had a bloody nipple discharge for 5 months. This lesion was confirmed by 14-gauge core needle biopsy. **A**, Conventional image showing posterior acoustic enhancement. **B**, Compound image showing no discernable posterior enhancement and a distinct echo texture in the solid portion of the mass.

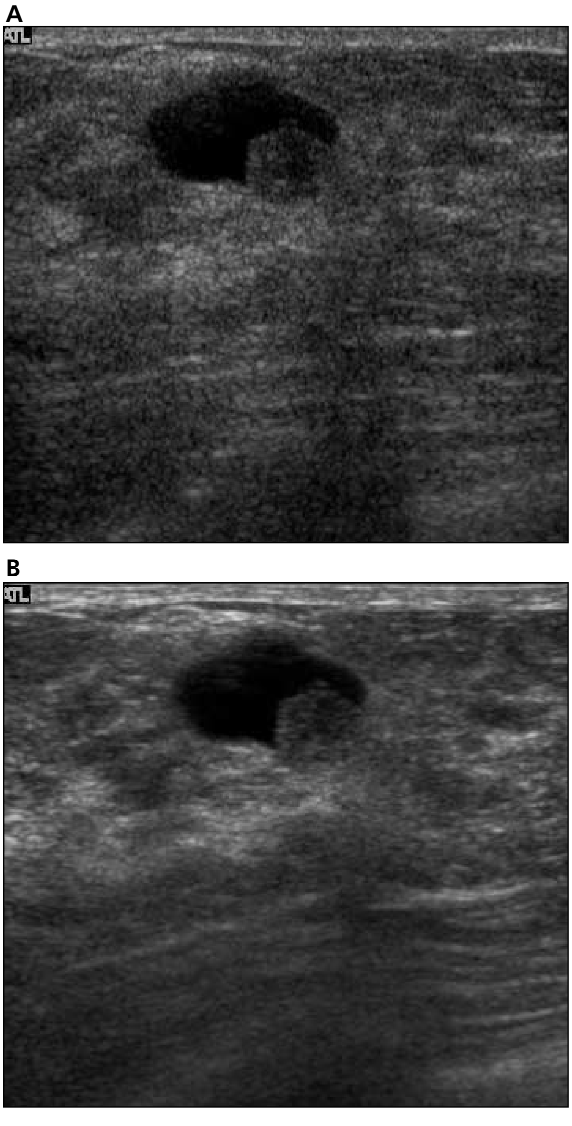


Figure 13. Granulomatous mastitis in a 35-year-old woman who had painful swelling for 5 months. This lesion was confirmed by 14-gauge core needle biopsy. **A**, Conventional image showing slight posterior acoustic enhancement and an indistinct lesion margin. **B**, Compound image showing no discernable posterior enhancement and a distinct lesion margin.

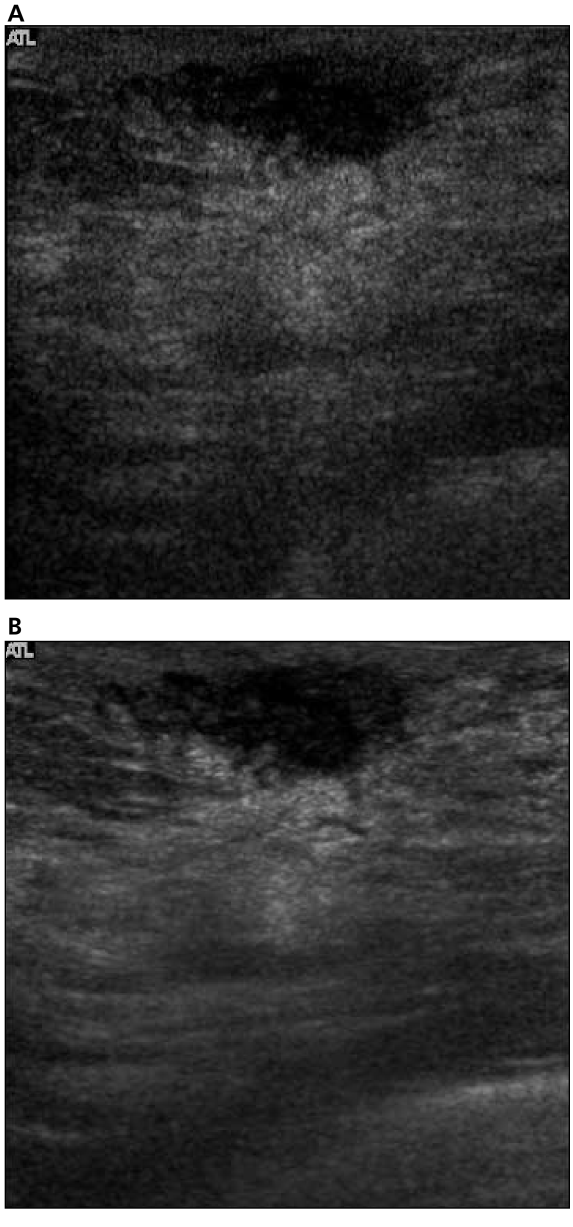
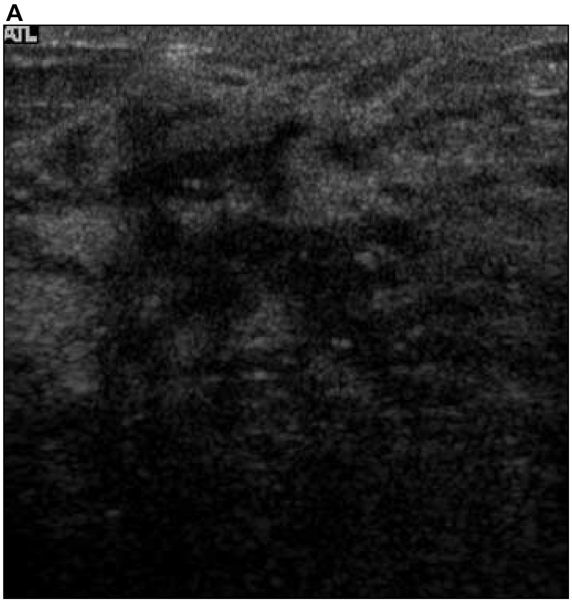


Figure 14. Ductal carcinoma in situ in a 58-year-old woman who had a palpable mass for 1 year. This lesion was confirmed by 14-gauge core needle biopsy. **A**, Conventional image showing subtle microcalcifications within the breast parenchyma. **B**, Compound image showing enhanced delineation of microcalcifications within the breast parenchyma due to improved spatial and contrast resolution.

A



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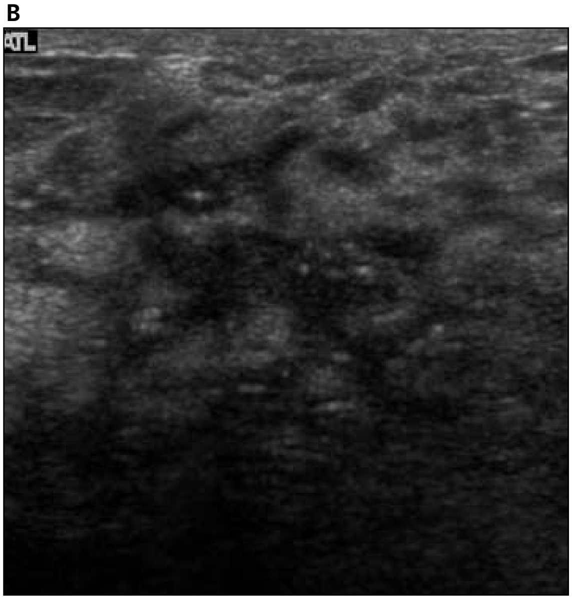


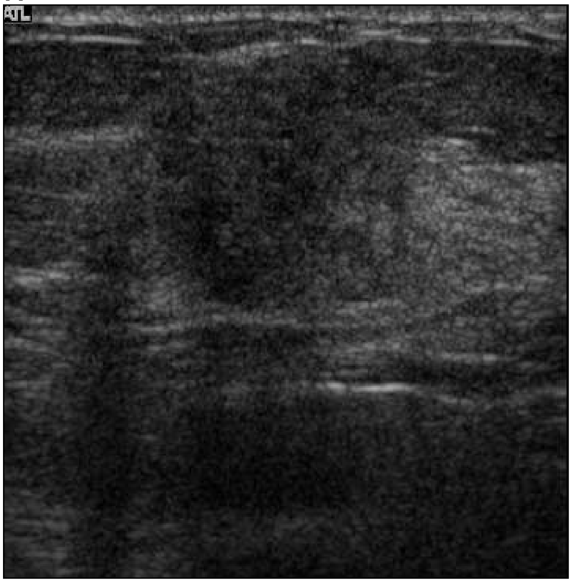
Figure 15. Infiltrating ductal carcinoma in a 40-year-old woman who had a palpable mass for 5 months. This lesion was confirmed by 14-gauge core needle biopsy and partial mastectomy. **A**, Conventional image showing an indistinct margin and an internal echo texture. **B**, Compound image showing better characterization of the margin and enhanced delineation of the internal architecture.

A

B

Figure 16. Mucinous carcinoma in a 51-year-old woman who had a palpable mass for 2 months. This lesion was confirmed by 14-gauge core needle biopsy and radical mastectomy. **A**, Conventional image showing an indistinct lesion margin and a less delineated posterior lesion margin due to posterior acoustic shadowing. **B**, Compound image showing a clearer lesion margin and better delineated posterior lesion margin due to decreased acoustic shadowing.

A



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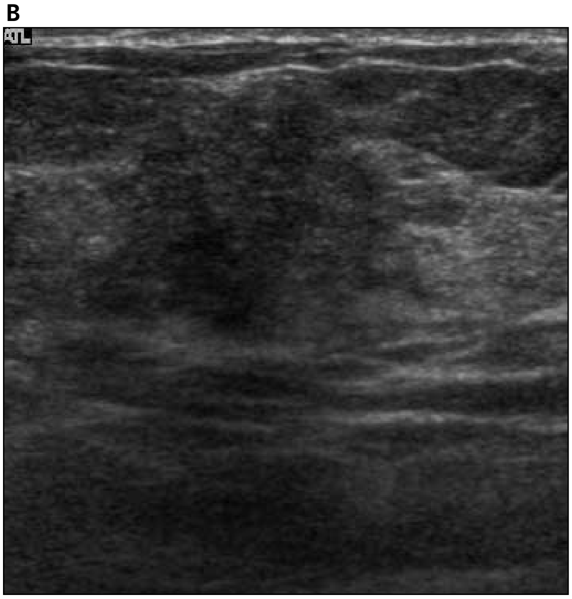

Figure 17. Postsurgical scar in a 43-year-old woman who had a palpable mass after excision for a fibroadenoma 1 year previously. This lesion was confirmed by 14-gauge core needle biopsy. **A**, Conventional image showing an indistinct lesion margin and a less delineated posterior lesion margin due to posterior acoustic shadowing. **B**, Compound image showing a clearer lesion margin and a better delineated posterior lesion margin due to decreased acoustic shadowing.

A

B

Figure 18. Postsurgical hematoma in the axilla of a 60-year-old woman with axillary swelling after partial mastectomy and axillary dissection for breast cancer. This lesion was confirmed by 20-gauge aspiration. **A**, Conventional image showing distinct lateral shadowing and posterior enhancement. **B**, Compound image showing decreased lateral shadowing and posterior enhancement.

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B

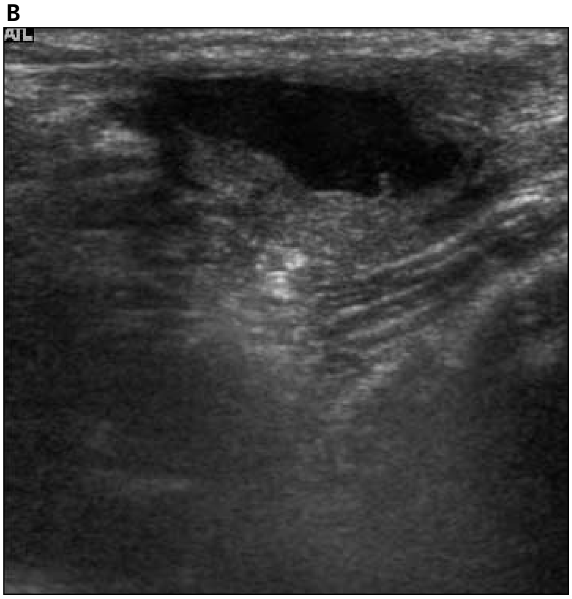
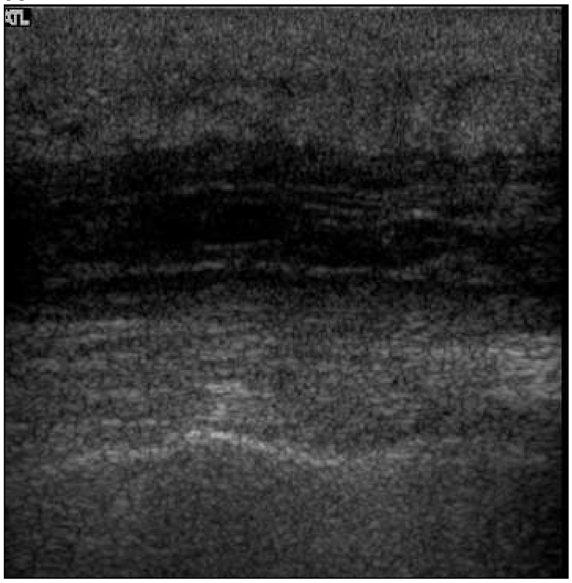


Figure 19. Postsurgical hematoma in the mastectomy site of a 68-year-old woman who had follow-up ultrasonography after radical mastectomy for invasive ductal carcinoma 3 months previously. This lesion was not seen on the follow up ultrasonography. **A**, Conventional image showing the organized hematoma. **B**, Compound image showing more distinct internal septa and posterior normal muscle bundles.

A



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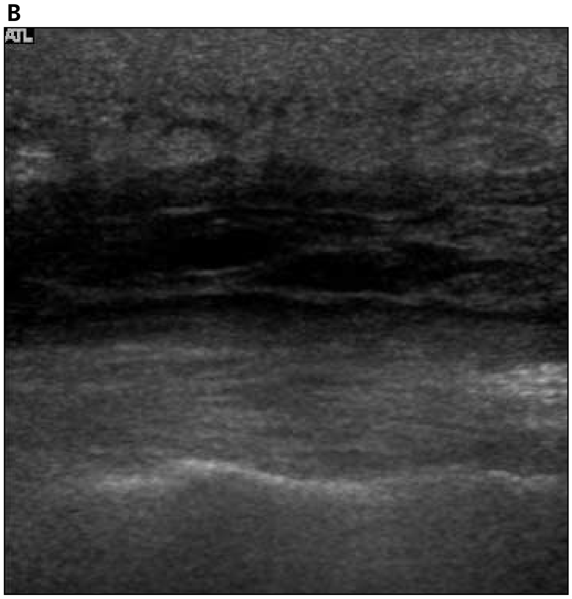

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