Practical value of the extended field of view (EFOV) modality in the US imaging of the breast

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Learning objectives

This exhibit offers a fulfilled pictorial guide to the possibilities of extended field of view (EFOV) images in breast imaging.

Images for this section:

**Fig. 1:** Drawing 1
Background

The size of the field of view (FOV) i.e. the bidimensional space where the scanned area is continuously displayed on the monitor, is typically small, particularly for high-resolution transducers. Consequently, the operator has to continuously move the probe with to-and-fro, rotational, and angulational movements to explore the entire breast and to define the anatomical relationship between the various normal and abnormal structures encountered. The simultaneous display of various normal and abnormal findings is difficult or impossible. Additionally, when the examination has been completed, becomes difficult to mentally reconstruct the whole spectrum of findings staring from single (on paper or electronic) images.

The FOV of a linear probe in rectangular and it is limited by the frontal length of the probe, usually being of four centimeters. It is possible to increase the scan panoramic view by freezing the scan and then moving to the adjacent section with a splicing maneuver (dual imaging), by using a larger probe (for example those 6 cm in length), or finally by using a trapezoid scan, that is an electronic opportunity offering a FOV progressively larger in its deepest part (image bottom). Nevertheless, this does not significantly changes the problems of panoramicity, that particularly at level of the breast are relevant.

Real-time, extended-FOV (EFOV) sonography is based on electronically extending the acquired image plane obtaining wide, high-quality gray-scale (eventually also with color or power-Doppler) images (Drawing 1 on page ). While the possibilities of EFOV scanning have been recognized by many years, real-time EFOV Sonography is available from a few time. Consequently, the opportunities allowed by real-time EFOV imaging in breast diagnosis have been mentioned in some textbook [1-3] and reviews on the technological advances of breast sonography [4-7]. Nevertheless, no paper has specifically highlighted the wide iconographic opportunities allowed by this option of modern, state-of-art scanners. In this exhibit we illustrate the possibilities, limitations, pitfalls, and practical value o real-time, EFOV reconstruction in the sonographic evaluation of various breast abnormalities.
Fig. 1: Twenty-nine years old woman with palpable breast mass (histologically-proven phylloid tumor). Echoic lesion, well defined and relatively homogeneous (cystic defects). The entire extension of the mass is not included in the conventional scan (A) or in the trapezoid FOV scan (B) but only in the EFOV scan (C), allowing an effective measurement (54x35 mm). Nevertheless, the mobility of the mass causes a stairstep artifact (arrows in C). D, Gadolinium-enhanced T1 axial magnetic resonance scan showing the well-defined, enhancing mass (arrows).
Imaging findings OR Procedure details

EFOV Methodology in Breast Imaging

Similarly to the water-bath immersion scanners of the 80s, but with a better spatial resolution, EFOV sonography allows providing two-dimensional survey images of the whole breast (in cross section, of course) or of large portions of it, such as an entire quadrant. The image is obtained in real-time, with standard probes, by a manual, interactive, translational movement of the transducer along patient skin. The operator tracks, while moving laterally his linear probe, the area of interest and obtains a large and not-significantly deformed image [8-11]. These images are transformed geometrically in relation to the calculated probe movement and each image is progressively summed to the previous ones into a final EFOV reconstruction. In other words the scanner performs speckle tracking to position the sequential frames correctly.

While the images are acquired, it is also possible to make some correction, as the operator recognizes that the manual movement as not been satisfactory or than for any reason the image does not display adequately the findings. As a matter of facts, the system incorporates an erase and recalculate function if the probe motion is reversed.

EFOV images can be obtained quickly, with 2-3 attempts usually enough to have an adequate reconstruction.

Typically EFOV images are obtained or an entire breast quadrant or, less commonly, for the whole breast. The operator must consider that the larger the area he scans the small the final reconstruction will be and it will be more easy to have artifacts or other undesired distortions. Consequently we suggest scanning only the area that is really useful to enclose in the final EFOV image. Additionally, it is important to obtain these images in a standardized way, posing on the right of the image the right side of the patient (this aside from the acquisition direction, is right to left or left to right). Labels indicating reference areas such as the nipple and the axilla are useful, as well body markers indicating the position and the orientation of the probe when the EFOV image has been obtained. Radial scanning would be ideal, because of the anatomically-oriented final image enclosing the nipple and the axillary region.

The operator should avoid having final reconstructed image too small, losing in this way the morphologic and structural detail of the abnormalities enclosed. An indication appears on the screen to highlight the percentage of size loss, which obviously is proportional to the scan length. We suggest to use the highest frequency allowed (modern transducers are multifrequency) and to regulate the scan depth rather superficially, to have final image eventually lacking of the deepest planes but depicting the relevant abnormalities with an adequate size and resolution.
A standardized acquisition sequence is useful both for the operator, when comparing different studies of the same patient and for the referring clinician, when watching patient documentation [7]. As a matter of facts, archived EFOV images, both as paper illustrations or as stored electronic images (inside the scanner, in a personal computer, or into the PACS), are useful from various points of view. The sonography study reporting can be more detailed, including data such as the distance between multiple lesions or between these lesions and anatomical markers such as the nipple. This information is not usually included in reports, although in some laboratory the distance from the nipple is approximately calculated by using the length of the array as a measure.

The serial morphological and dimensional assessment of large lesions by the operator becomes easier and also more objective. The correlation with wider display images of the breast from mammography and magnetic resonance is improved. The image evaluation by the clinician, both during patient visit and in the operatory room, becomes more effective.

**EFOV Applications in Breast Imaging**

A useful aspect of EFOV reconstructions is the ability to measure the size of very large abnormalities, including large solid or cystic tumor masses, extended infiltrative lesions, and fluid collections [1-6]. Consequently it becomes possible to display and measure the real extent of the abnormality is a single image (Fig.1 on page 7), (Fig.2 on page 8), (Fig.3 on page 9), (Fig.4 on page 10), (Fig.5 on page 11), (Fig.6 on page 12). This is particularly useful for serial sonography studies in patients with locally-advanced breast tumors undergoing neoadjuvant chemotherapy, to document precisely and objectively the morphological and dimensional changes induced by the treatment.

EFOV images allow a better display of the topography between a breast abnormality and landmarks such as the nipple or the axilla, whose distance from the lesion can be documented and eventually measured [1-6]. It is possible to enclose multiple lesions, of the same nature or of different nature, such as multiple nodules or also axillary lymphadenopaties (Fig.7 on page 13), (Fig.8 on page 14), (Fig.9 on page ). This is particularly helpful for displaying the spatial relationship of multifocal or multicentric malignancies, with an accurate measurement of the distance separating each tumor focus. Studies carried out in phantoms have overtly confirmed the accuracy and reproducibility of measurements from EFOV reconstructions [12,13].

Long and tubular structures such as the galactophores (or eventually the vessels) can be displayed panoramically in a single image (Fig.10 on page ). Therefore it becomes possible to show panoramically the dilated ducts, the spatial relationship of lesions located internally or externally to galactophores, and measuring the distance from the nipple (Fig.11 on page ), (Fig.12 on page ). Also the spatial display of the...
intraductal component of ductal carcinomas can be improved, obtaining images showing simultaneously the infiltrative mass and the hypoechoic strands directing toward the nipple (Fig. 13 on page ).

The reconstructed final image can result distorted because of patient motion (active movements, breath, heartbeat, etc.), determining a discontinuity among the various successive frames with a typical stepladder artifact. Nevertheless, a solidly-standing hand holding the probe and an adequate knowledge of the risk of artifactual images usually are enough to obtain good quality images. The pressure with the probe must be constant, not too hard to avoid deformation of the skin surface and not too soft otherwise the probe-to-skin contact will not be continuous and empty areas will result among the frames. Skin irregularities (protruding or retracting lesions, large scars, cutaneous abnormalities, etc.) will result in poor final images and will sometime make EFOV images ineffective or at least inadequate to display the abnormality. Benign, mobile nodules, especially large in size, can move during the progression of the probe and result in distorted final reconstructions.

Images for this section:
Fig. 1: Twenty-nine years old woman with palpable breast mass (histologically-proven phylloid tumor). Echoic lesion, well defined and relatively homogeneous (cystic defects). The entire extension of the mass is not included in the conventional scan (A) or in the trapezoid FOV scan (B) but only in the EFOV scan (C), allowing an effective measurement (54x35 mm). Nevertheless, the mobility of the mass causes a stairstep artifact (arrows in C). D, Gadolinium-enhanced T1 axial magnetic resonance scan showing the well-defined, enhancing mass (arrows).
Fig. 2: Forty-one years old woman with locally-advanced breast cancer. Ill-defined and inhomogeneous mass (arrows). A, The entire extension is not included in the conventional scan. B, The entire extension is not included in the trapezoid FOV scan. C, The EFOV scan depicts adequately the mass extension (arrows). D, Gadolinium-enhanced T1 axial magnetic resonance scan confirming the large and ill-defined enhancing lesion (arrows).
Fig. 3: In situ ductal carcinoma with invasive component. A, The large infiltrating hypoechoic tissue with microcalcifications is not entirely included in the trapezoid FOV scan. B, The EFOV scan allows a wide display of the multi-quadrant disease.
**Fig. 4**: Seventy years old woman with chest wall recurrence of a breast carcinoma previously treated with mastectomy. The hypoechoic mass adjacent to the ribs is not entirely documented in the conventional scan (A) while it is well shown in the EFOV scan (51x20 mm) (B).
Fig. 5: Fifty-five years old woman with axillary lymphocele after quadrantectomy and lymphadenectomy. The large collection is not entirely documented in the trapezoid scan (A) while it is entirely shown in the EFOV scan (B).
**Fig. 6:** Thirty-eight years old woman with additional mastoplassty. Panoramic display of the subglandular prosthesis (arrows).
Fig. 7: Fifty-two years old woman with breast carcinoma within the external upper quadrant, with metastatic lymph node in the axillary prolongation. The malignant nodule (A) and the lymph node (B) are simultaneously displayed on the EFOV reconstruction (arrows, C), where the distance among the two is also measured. T= tumor. N= lymph node.
**Fig. 8**: Sixty-four years old woman with bifocal breast cancer. The conventional scan (A, arrows) does not allow the simultaneous visualization of both nodules, well shown instead in the EFOV scan (B, arrows). C, Maximum intensity projection image from gadolinium-enhanced T1 axial magnetic resonance scan confirming the two enhancing lesions (arrows).
Conclusion

In conclusion, EFOV images can partly overcome the known panoramicity limitations of US. These images are more comprehensible for the clinician and allow a better comparison between serial exams. EFOV scans allow an improved assessment of nodules topography, a more accurate measurement of lesion size, and a better depiction of ductal extent.

Images for this section:

Fig. 1

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Images for this section:
Fig. 2
References


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Images for this section:

Fig. 1