Extended Field-of-View Sonography
Advantages in Abdominal Applications

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Objective. To show the advantages of extended field-of-view sonography in abdominal applications.

Methods. Thirty-one cases were prospectively analyzed in our study. Extended field-of-view images were obtained when the radiologist decided that they would offer potential advantages for the examination. When extended field-of-view scanning was used, the radiologist determined prospectively whether it was useful according to several categories. Images were obtained with a 2- to 5-MHz curved array transducer or 4- to 9- and 5- to 12-MHz linear array transducers.

Results. Extended field-of-view sonography provided several potential benefits over conventional sonography in the abdominal area. The advantages of extended field-of-view sonography were better demonstration of the spatial relationship between lesions and adjacent normal structures in 18 cases (58%), accurate quantification of sizes or volumes of large organs or lesions in 16 (52%), better display of the extended and tubular structures in 6 (19%), usefulness for clinical consultations in 7 (23%), and documentation comparable with that of computed tomography or magnetic resonance imaging in 10 (32%).

Conclusions. Extended field-of-view sonography provided the anatomic context of the lesion in its surroundings and allowed precise measurement and tracing of the extended and tubular structures. The method has notable advantages and clinical applications.

Key words: abdominal sonography; extended field of view; ultrasound technology.

Abbreviations
CT, computed tomography; EFOV, extended field-of-view; GI, gastrointestinal; MRI, magnetic resonance imaging

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Compared with other methods, such as computed tomography (CT) and magnetic resonance imaging (MRI), sonographic transducers are small and mobile. They can be used in every position and for every view, which allows application to any part of the body. However, the field of view, especially with high-resolution linear arrays, is small and usually excludes identifiable landmarks. Consequently, sonography may have some limitations in comparison with CT and MRI.

The recently developed extended field-of-view (EFOV) imaging technology facilitates possible panoramic images with no loss in resolution by the manual movement of a real-time ultrasonic probe in the direction of the transducer array. This image-processing technology estimates translation and rotation of the probe by comparing successive images during probe movement, and
no probe position-sensing mechanism is necessary. The images transformed geometrically according to the estimated probe motion are entered into the EFOV image buffer and combined with previous images to produce an EFOV image. Extended field-of-view images enable the acquisition and recording of a panoramic image up to 60 cm in length and offer new possibilities for viewing topographic anatomic structures. Larger organs or pathologic structures can be displayed in 1 image together with their surroundings. Many clinical applications of EFOV sonography and its utility have been reported. To date, it has been reported that EFOV imaging plays its most important role in relatively superficial small parts imaging. One article about the clinical utility of EFOV even reported the limitation and ineffectiveness of abdominal applications.

Here we present our clinical experiences to show the advantages of EFOV sonography in abdominal imaging, which to our knowledge have not yet been reported. In our study, the cases were arbitrarily chosen to show the advantages of EFOV in the abdominal area.

Materials and Methods

Over 3 months, 31 consecutive EFOV examinations (in 17 men and 14 women; mean age, 52 years; range, 38 to 70 years) were performed in our department. All examinations included in the study were performed with 1 of 2 sets of sonographic equipment: a Sonoline Antares system (Siemens AG, Munich, Germany) and an HDI 5000 scanner (Philips Medical Systems, Bothell, WA). In the former, 2- to 5-MHz curved array and 4- to 9-MHz vector array transducers were used; in the latter, 2- to 5-MHz curved array and 5- to 12-MHz linear array transducers were used. All examinations were performed by 1 radiologist (S.H.K) experienced in abdominal sonography and EFOV scanning. Extended field-of-view images were obtained when the radiologist decided that they would be beneficial for the examination.

The patients in this study were chosen at the discretion of the radiologist to show the additional benefit from EFOV imaging. When EFOV scanning was used, the radiologist determined prospectively whether it was useful according to the following categories: (1) better display of the spatial relationship between lesions and adjacent normal structures, (2) accurate quantification in measuring the sizes or volumes of large organs or lesions, (3) better scanning of the extended and tubular structures, (4) usefulness for clinical consultations, and (5) documentation comparable with that of CT or MRI. In addition, if the diagnosis could be made only on the basis of the images acquired with the EFOV images, it was considered helpful in establishing the diagnosis.

Results

A total of 31 EFOV examinations were performed to evaluate the liver (n = 12), kidney (n = 7), gastrointestinal (GI) tract (n = 6), adrenal gland (n = 2), and others (n = 4). Among them, 22 cases (17 malignant and 5 benign) were confirmed histologically by surgery or biopsy, and 9 cases (all benign) were diagnosed on the basis of clinical and characteristic radiologic findings.

All 31 EFOV images were judged to be useful on the basis of 1 or more of the above categories: (1) better display of the spatial relationship between lesions and adjacent normal structures (n = 18, 58%), (2) accurate quantification in measuring the sizes or volumes of large organs or lesions (n = 16, 52%), (3) better scanning of the extended and tubular structures (n = 6, 19%), (4) usefulness for clinical consultations (n = 7, 23%), and (5) documentation comparable with that of CT or MRI (n = 10, 32%). However, EFOV sonography did not offer any additional information to establish the diagnosis in any of the cases.

Discussion

Extended field-of-view technology was first introduced by Weng and colleagues in 1997 and widely applied to many fields of sonography. In our study, EFOV sonography was used in the field of abdominal sonography with several potential benefits, although it was not essential for the diagnosis. We present and discuss the abdominal applications according to the advantages of EFOV imaging.

Better Display of the Spatial Relationship Between Lesions and Normal Structures

In cases of large pathologic lesions, the relationship between lesions and adjacent structures was made clear with conventional sonography by mental reconstruction, but with EFOV imag-
ing, these relationships were clearly evident on a single image (Figs. 1–4). This is especially apparent with high-resolution linear arrays, which have a small field of view and in which the identifiable landmarks are usually excluded.

Our case of appendiceal mucocele shows this advantage (Fig. 1). Whereas a conventional real-time sonogram shows only the part with the abnormality, the EFOV image provides a complete picture, including the normal proximal appendix and the mucocele filled with echogenic material. It is therefore immediately apparent that the lesion is confined to the distal portion of the appendix. The EFOV imaging provides an overview of the whole lesion. Before using EFOV imaging, we usually used a curved linear transducer (5 MHz) to show the relationship of the whole appendix to the adjacent structures (cecum or periappendiceal abscess), even though there was some sacrifice in terms of resolution. Extended field-of-view images show the normal or abnormal appendix, adjacent structures, and their relationships, all in high resolution.

In many cases of testicular abnormality, it is also difficult to produce side-by-side images of a normal and abnormal testis in a single conventional sonogram. This disadvantage is also overcome by the EFOV technique. In our case of testicular seminoma, the left testis was replaced by a huge heterogeneous, echoic mass and was easily compared with the normal right testis in a single EFOV image (Fig. 4).

**Accurate Quantification in Measuring the Sizes or Volumes of Large Organs or Lesions**

On conventional sonography, anatomic structures or lesions larger than the dimensions of the sonographic transducer can only be documented as a series of sector images. Because sonographic measurement is operator dependent, sonographic evaluation of changes in lesion size is likely to be less accurate than CT or MRI evaluation. Therefore, for objective judgment of a therapeutic effect, additional cross-sectional imaging modalities such as CT and MRI have been required. If sonography can provide accurate and reproducible measurements, the extra costs of additional CT or MRI scans could be avoided.

Until now, the following options have been available to the sonographer for measuring large lesions or anatomic structures that cannot be encompassed in a single conventional sonogram: to use a lower-frequency curved array transducer; to use a trapezoidal field of view, which resulted from the capability of lateral beam steering; and to use the side-by-side display in the split-screen mode. However, these alternatives have limitations in resolution and accuracy. Fortunately, the accuracy of measurement by the EFOV technique has been proved by 2 previous articles describing in vitro phantom studies in which relative errors of less than 4% to 5% were reported.1,9

**Figure 1.** Appendiceal mucocele in a 58-year-old man. **A**, Transverse EFOV image showing a dilated, mucus-filled portion of the appendix (arrows) with continuity to the normal appendix (arrowheads). **B**, Conventional sonogram showing only a part of the lesion.
Figure 2. Hemorrhagic cyst of the left adrenal gland in a 38-year-old man. A, Conventional sonogram from a high-frequency linear array transducer showing only a part of the cystic mass in the left upper quadrant. B, Although virtually formatted, trapezoidal imaging with beam steering produces a high-resolution image with a wider acceptance angle than that of a conventional high-frequency transducer. The inferior portion of the main mass is still not covered, and the anatomic spatial relationship between the lesion and adjacent structures is not evident. C, Extended field-of-view image from the same transducer as in A and B fully showing the adrenal lesion and better depicting the anatomic spatial relationship between the spleen (S) and left kidney (K). This image is also comparable with a coronal magnetic resonance image (D).
Because measurements of large structures on EFOV images are accurate and reproducible, sequential EFOV sonograms allow monitoring of large neoplasms or fluid collections during therapy or follow-up periods (Figs. 3–5). Indeed, in one of our patients with an abdominal lymphoma, which manifested with extensive retroperitoneal lymphadenopathy, sequential EFOV sonograms at 3-month intervals were useful for monitoring the therapeutic response (Fig. 3). Accurate measurement on EFOV imaging is applied to the area as well as the length. A 45-year-old woman with a diagnosis of autosomal dominant polycystic kidney disease had right upper quadrant pain and fever and visited our emergency department. Sonography with the EFOV technique was performed and revealed variably sized cysts replacing the whole liver. One of these cysts had echogenic debris with a fluid-fluid level suggesting a complication such as hemorrhage or infection. The EFOV image gave us objective information about its relative location in the liver and accurate measurements of the area and volume of the complicated cyst (Fig. 6). On the basis of that information provided by the EFOV image, we successfully treated her with aspiration of the contents and sclerotherapy using the estimated volume of the sclerosing agent.

**Scanning the Extended and Tubular Structures**

In GI tract diseases, the tubular and tortuous nature of the GI tract makes a complete understanding of the full context of the disease difficult, in particular the relationship between cause and effect. A correct diagnosis is only possible by close follow-through of the GI tract in real-time imaging and mental reconstruction of these images. In conventional sonography, proof of the diagnosis has only been available on the basis of pieces of the images. Extended field-of-view images solve this problem (Figs. 7 and 8). In one of our cases of small-bowel obstruction with a jejunal bezoar (Fig. 7), the EFOV image provided us with objective information by showing the echogenic mass in the bowel and a dilated, fluid-filled bowel loop proximally in a single image. This concentrated confirmation was...
convincing proof of the diagnosis for other examiners, including our supervisor. With this advantage, EFOV imaging is also useful in biliary disease (Fig. 9).

Usefulness for Clinical Consultations
The lack of objectivity and reproducibility are two of the weak points of sonography compared with CT or MRI. Many sonograms cannot be interpreted exactly by a third person except in some selected cases. Indeed, in our hospital, sonography performed in other hospitals is not included for outside consultation, contrary to other cross-sectional modalities (CT, MR, and positron emission tomography), and is routinely reordered for additional sonographic informa-

Figure 4. Testicular seminoma in a 53-year-old man. A, Conventional sonogram from a curved linear array transducer incompletely showing the large mass. B, Extended field-of-view image fully showing the left testis, which is replaced by a heterogeneous mass. This image better defines the location of the lesion by showing the normal right testis (R).

Figure 5. Two hemangiomas in a 38-year-old woman. This EFOV sonogram shows 2 heterogeneous echogenic masses (single arrows) with anatomic landmarks of the middle (arrowhead) and left (double arrows) hepatic veins. We can perform reproducible measurement of the lesions in sequential sonography by obtaining another image with the same anatomic landmarks.

Figure 6. Complicated hepatic cyst in a 45-year-old woman with polycystic kidney disease. She had right upper quadrant pain and fever. A, Extended field-of-view image showing multiple variably sized cysts replacing the whole liver. One of them has inner echogenic debris with a fluid-fluid level (arrow), suggesting a complication such as infection or hemorrhage and thought to be the cause of her symptoms. B, Area of the complicated cyst (33.62 cm²) calculated with a measuring tool.
According to one report, improvement of diagnostic capability when an EFOV image was used compared with only conventional sonograms ranged from 58% to 76% among radiology residents but was not significant among urology residents (44%–50%). However, several examples showed the advantages of EFOV for communicating with referring clinicians (Fig. 10). Overall, those data do not reduce the clinical usefulness of EFOV imaging. Because EFOV images contribute to improved diagnostic capability for radiologists, referring clinicians may be less likely to order repeated sonography when an outside sonogram with EFOV images is available. For example, in patients with colon cancer, metastatic masses to the liver are considered resectable if their numbers are fewer than 4. In one of our patients with colon cancer and 2 metastatic masses of the liver, the EFOV sonogram simplified the referring surgeon’s decision.

Figure 7. Jejunal obstruction with a phytobezoar in a 70-year-old woman. A, Conventional sonogram showing only a part of the dilated small bowel. B, Extended field-of-view image showing an echogenic mass (arrow) in the bowel lumen and a proximal dilated bowel loop (arrowheads). C, Small-bowel follow-through study showing an ovoid filling defect (arrow) in the jejunum, a distended stomach, and a dilated proximal jejunum. D, Computed tomographic scan showing low, attenuated, masslike material with inner bubbly air suggesting the bezoar (arrow).
regarding the preoperative plan for hepatic metastasectomy, because the 2 metastatic masses of the liver were shown on a single sonogram with anatomic landmarks.

**Documentation Comparable With That of CT or MRI**

Extended field-of-view images show anatomic circumstances with a clarity comparable with that provided by CT or MRI, according to the findings in our cases (Figs. 2, 11, and 12). One of the advantages of sonography is the possibility of real-time scanning without restriction of the anatomic plane. In conventional sonography, this advantage is reduced by the limited field of view. Because EFOV images comparable with the CT or MRI plane are easier to communicate to clinicians than conventional real-time sonograms, referring clinicians may be more confident in the scan results and may therefore be less likely to order confirmatory CT or MRI scans. In addition, an EFOV sonogram provides an image comparable with a three-dimensional reconstructed image, such as a curved multiplanar reconstruction, as well as with an image in the orthogonal plane of CT or MRI.

**Figure 8.** Advanced gastric cancer (Borrmann type IV) in a 63-year-old man. This EFOV image depicts the entire stomach with a thickened wall suggesting linitis plastica (arrows). Note the intact duodenal bulb (arrowheads) and large amount of ascitic fluid (A) suggesting peritoneal carcinomatosis.

**Figure 9.** Left intrahepatic duct stone in a 45-year-old woman. This axial EFOV sonogram shows an echogenic stone (arrow) in the left main duct and dilated distal ducts (arrowheads) in a single image.

**Figure 10.** Two hepatic metastases from colon cancer in a 52-year-old woman. **A,** Two metastatic masses (arrows) in hepatic segments 8 and 3 shown in split-screen mode. However, this image is not conclusive to the referring surgeon for making a preoperative plan for hepatic metastasectomy. **B,** Extended field-of-view image showing the 2 metastatic masses (arrows) simultaneously, which is useful for preoperative planning.
Conclusions
One of the difficulties in sonography is trying to obtain a still image that does justice to information shown in a real-time scan. It can be difficult for a sonography user to convey that information to a third person. Extended field-of-view images offer several advantages over conventional gray scale images. Extended field-of-view imaging can provide a more readily understood image of the anatomic relationship between structures than can a series of conventional images and can encompass large structures in a single view. With EFOV imaging, sonographic findings can be conveyed to other specialists easily, including information comparable with that from CT or MRI. All the above advantages may facilitate communication with referring clinicians. Therefore, this imaging method should prove to be a useful documentation tool. The selected use of the EFOV technique in abdominal imaging will provide the concentrated information of existing applications and will enable advances in new ones.

Figure 11. Lymph node metastasis in a 58-year-old woman with stomach cancer. A, Extended field-of-view sonogram showing hydronephrosis of the left kidney (H) and multiple conglomerated lymphadenopathies in the aortocaval (filled arrow), retrocaval (arrowhead), and left paraaortic (open arrow) regions as the cause. Note the intact pelvicaliceal system in the right kidney (R). This image provides information comparable with that from an axial CT scan (B) and enables the referring physician to confidently interpret the scan.

Figure 12. Horseshoe kidney with multiple cysts in a 55-year-old man. A, Conventional sonogram showing only the isthmus portion (arrow) of the horseshoe kidney. B, Axial EFOV sonogram fully showing the horseshoe kidney with several cysts (filled arrows) in both kidneys. Note the isthmus portion between the aorta (arrowhead) and the compressed superior mesenteric vessel (open arrow). It was not possible to obtain such an image with conventional axial CT (not shown).
References


