Three-dimensional Ultrasound Imaging

- Three-dimensional (3D) ultrasonography employs a transducer that records spatial information; the entire data set is stored for subsequent analysis.
- 3D imaging adds accurate volume measurements of lesions and structures, which is not available with current 2D ultrasound imaging.
- The data set can be used to view lesions or structures in multiple planes, volumetric reconstructions and measurements, and surface views.
- 3D ultrasonography has advantages in applications such as gynecological, neonatal brain, and thyroid imaging.

Ultrasoundography is a widely used modality for the diagnosis and monitoring of diseases such as those that affect the pelvic organs, the thyroid, and the neonatal brain. Traditionally, two-dimensional (2D) ultrasound has been used to acquire planar “snapshots” that, in some cases, can be used to deduce a three-dimensional (3D) mental concept or an estimated volume. However, 2D imaging has some inherent limitations. For example, some scan planes cannot be obtained by 2D imaging, and estimates of volume must make an assumption of a regular geometric shape, such as an ellipsoid.

### 3D Ultrasound

Whereas a 2D scanner stores only those images that the sonographer manually selects, a 3D ultrasound system stores all of the data continuously as the ultrasound probe is guided over the region of interest. In some cases, automated mechanically driven volume transducers are used to sweep over a predefined area. These offer the best image resolution, but the field of view is restricted compared to freehand scanning. 3D imaging has the added advantage of more rapid imaging because it is not necessary to carefully select a single image for acquisition. Furthermore, 3D imaging reduces the need to recall patients for additional images, as 3D volumetric ultrasound data can be comprehensively reviewed at the workstation after the examination.

Once the data are stored, they can be manipulated to form images comparable to those seen in CT or MRI; that is, images can be displayed in any given plane. Multiplanar displays are commonly shown, with three orthogonal displays that all center on a specific point. In addition, data can be manipulated to produce 3D representations including surface rendered images, maximum intensity projections, and volumetric images. Fluid in a cavity such as the uterus can be shown as anechoic (black) within a light colored uterine wall or opaque (white), in an image comparable to an x-ray hysterosalpingogram. 3D imaging is often combined with conventional 2D imaging as well as color Doppler imaging and power Doppler imaging.
**Gynecological Imaging**

In 2D ultrasound imaging of the uterus, the bony structures of the pelvis prevent scanning from the pelvic sidewall, while the restricted mobility of the endovaginal probe also limits the views that can be obtained. For these reasons, it is not possible to obtain coronal images directly. However, using 3D volumetric ultrasound, it is possible to reconstruct coronal images, making it possible to examine the curvature of the fundus, the shape of the endometrium, and the cervical canal extending inferiorly from the lower endometrial cavity. Coronal views make it possible to clearly show the presence of uterine anomalies and, for example, to differentiate between arcuate, unicornuate, septate, and bicornuate uteri, all of which are difficult to distinguish on standard 2D imaging. In addition, 3D ultrasound has significant advantages for the diagnosis of endometrial disease, the localization of uterine fibroids, and the precise depiction of the position of intrauterine contraceptive devices (Figures 1,2,3).

Sonohysterography, in which transvaginal ultrasound images are acquired while the uterine cavity is distended with saline, is a sensitive technique for the evaluation of the endometrial lining and the myometrium. However, using traditional 2D techniques, it is challenging to derive a 3D concept of the endometrial cavity anatomy and the location and morphology of lesions. Using 3D volumetric ultrasound techniques, a series of contiguous images of the distended endometrial cavity can be acquired in less than two minutes. These images can be analyzed after the patient has left the examining room, reducing total examination time and patient discomfort. In addition to reconstructed multiplanar views, it is possible to perform perspective volume rendering to create realistic video fly-through video sequences that mimic hysteroscopy.

Transvaginal 3D ultrasonography is also helpful for assessing ovarian and follicle volumes. Although volume estimations from 2D images are sufficiently accurate for regular ovoid structures, 3D imaging is especially useful for assessing irregularly shaped structures, such as pelvic masses. In addition, 3D ultrasonography allows accurate measurements of follicle volumes, which are often distorted by adjacent follicles, and also permits accurate follicular counting.

3D ultrasonography also has added value for evaluating adnexal masses. In addition to volumetric measurements and the assessment of echogenicity, 3D power Doppler ultrasonography can be used to visualize and quantify blood flow. It has been shown that the central localization of blood vessels, the mean gray index, and the flow index may be important indicators that distinguish benign from malignant lesions.

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**Figure 2.** A coronal reformation of the endometrial cavity (outlined by short arrows) shows a low-lying T-shaped IUD in the endocervical canal (long arrow).

**Figure 3.** A) A 3D reformatted coronal ultrasound image shows two echogenic foci above the uterine fundus (arrows). B) Pelvic CT confirmed transmural migration of the IUD (arrows).
Figure 4. 3D ultrasound images of an infant brain showing A) coronal, B) sagittal, C) axial and D) a 3D volumetric reconstruction of the left ventricle.

**Neonatal Brain**

Ultrasonography is the primary modality for cranial imaging of both premature and full-term neonatal infants. The open fontanel provides a window for ultrasound imaging and this technique is widely used for the evaluation of intracranial hemorrhage, which is commonly seen in newborn infants, especially those that are preterm. Ultrasonography of the neonatal brain is also commonly used to assess ventricular dilatation (Figure 4), periventricular leukomalacia, encephalopathy, and cerebral malformations.

Ultrasonography has an advantage over other imaging techniques such as MRI or CT in that the infant does not have to be moved to another location for imaging, no sedation is necessary, there is no ionizing radiation, it is relatively inexpensive, and it can be safely used repeatedly. 3D ultrasonography offers several advantages over traditional 2D methods, especially when automated scanning is used, which produces higher resolution images. Multiplanar images are helpful for depicting the precise location and size of lesions while volumetric images can be used to track changes in lesion size over time. Another important consideration is that the time needed for 3D image acquisition is less than two minutes, compared to over 10 minutes for traditional 2D ultrasound. This is especially significant for infants in neonatal intensive care because it results in less stress for the infant and a decreased likelihood for the disruption of catheters and endotracheal tubes.

Color Doppler 3D ultrasound can demonstrate the orientation of blood vessels and reconstructed images can depict the 3D vasculature in flattened maximum intensity projections. Such imaging of cerebral perfusion has the potential to detect and delineate ischemic areas, enabling an earlier diagnosis and more accurate follow up.
Thyroid

Ultrasonography is commonly used to evaluate thyroid masses and can be used to determine the volume of the thyroid gland, which is often relevant to radioiodine therapy dosing. In 2D ultrasonography, the thyroid volume is calculated using a formula that assumes that each lobe of the thyroid is an ellipsoid, based on measurements of the three axes. However, this technique is subject to interoperator variability, as the technologist must manually find the optimal plane in which to make the thyroid measurements. Moreover, since the gland is commonly irregularly shaped, there may be considerable under- or overestimation of the gland volume. In 3D ultrasonography, the volume is calculated from the 3D data set without these limitations and has been shown to be more accurate and reproducible than that derived from standard 2D imaging.

Scheduling

3D volumetric ultrasound can be performed at Mass General Imaging in Waltham, Mass General Imaging in Chelmsford, Mass General Imaging Chelsea, Mass General/North Shore Center for Outpatient Care, or the main MGH campus. It can be ordered online via the Radiology Order Entry (http://mghroe) or by calling 617-724-9729 (XRAY). Note that 3D ultrasound for neonatal brain is only performed at the main campus and 3D volumetric thyroid ultrasound will be available, starting in May, only at the main campus.

Further Information

For further questions about 3D ultrasound of the pelvis or of the thyroid, please contact Anthony Samir, MD, Abdominal Imaging and Intervention, Mass General Imaging, at 617-726-8396. For questions about 3D ultrasound of the neonatal brain, please contact Javier Romero, MD, Neuroradiology, Mass General Imaging, at 617-724-7095.

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References


