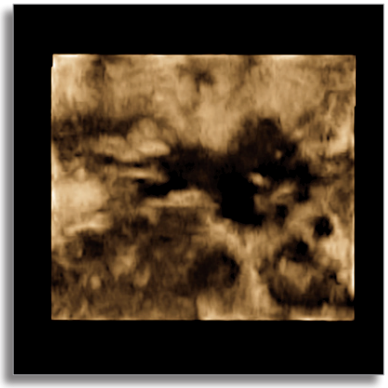

Volume imaging for your ultrasound department

Practical guide to getting started

This booklet provides clinicians with an easy-to-follow guide on both why and how to integrate volume imaging into your ultrasound labs. Case studies from European and North American sites provide compelling data on the impact volume imaging has had on improving the diagnostic results of their ultrasound departments.

PHILIPS

sense and simplicity

Below is a summary of results from a Philips European volume imaging survey. The key objective was to measure the impact of volume imaging on the ultrasound applications listed. Each site was asked to complete 50 studies and answer a series of "yes" or "no" questions. The percentages reflect the number of "yes" answers to the questions.

Results from European study – 293 cases

	Additional information increased confidence	Virtual rescanning improved surveillance or audit	Changed diagnosis	Increased confidence in lesion localization	Increased confidence in lesion vascular anatomy	Improved communication to referring physician	Changed imaging strategy	Improved exam efficiency and shortened exam time	Facilitated measurements
TOTAL 293 cases	**62%**	**71%**	**32%**	**50%**	**45%**	**57%**	**28%**	**62%**	**68%**

Application	Clinician and location
Liver 37 cases	**Etienne Danse, MD, PhD and Mohamed Kichouh, sonographer** St. Luc University Hospital, Université Catholique de Louvain, UCL – Brussels, Belgium
Renal 50 cases	**Simon T. Elliott, MD** Freemand Hospital – Newcastle upon Tyne, UK
Gyn 29 cases	**Giovanni Serafini, MD and Luca M. Sconfienza, MD** Radiology Unit, Santa Corona Hospital – Pietra Ligure, Italy
Breast 55 cases	**Ariel Saracco, MD** Bröstcentrum SöS – Stockholm, Sweden
Bowel 18 cases	**Etienne Danse, MD, PhD and Mohamed Kichouh, sonographer** St. Luc University Hospital, Université Catholique de Louvain, UCL – Brussels, Belgium
Peds/Misc 55 cases	**Michel Claudon, MD and M. Galloy, MD** Centre Hospitalier Universitaire – Nancy, France
Renal 49 cases	**J.M. Correas, MD and A.M. Tissier, MD** Necker University Hospital – Paris, France

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1. Volume imaging of an abdominal aortic aneurysm

Simon T. Elliott, MD
Freeman Hospital, Newcastle upon Tyne, UK

Key reasons to consider 2D plus volume imaging approach

Surveillance scanning of abdominal aortic aneurysm (AAA) requires meticulous attention to measurement detail in order to reduce inter-observer variation over time. Volume ultrasound provides a fast and efficient method of examination and security of imaging data, so that sequential examinations can be stored, reviewed and compared.

We have shown[1] that AAA measurements made using volume ultrasound are at least as accurate as conventional 2D scanning, and volume ultrasound offers significant advantages in terms of imaginative workflow processes.

How we do the exam

The volume ultrasound examination is based on our standard 2D AAA protocol. This consists of the mean of two sagittal, anteroposterior (AP) maximum diameters and the mean of two coronal transverse (TS) maximum diameters.

Anteroposterior

1. Place the volume transducer over the midline of the AAA in the sagittal plane (Figure 1).
2. Optimize the image (for example, using iSCAN, compression and harmonic).
3. Enter 3D/4D mode from the touchscreen.
4. Set sweep angle. (Since you are only interested in maximum diameter this is usually 30 to 40 degrees. Reduce the angle and you reduce movement artifact.)
5. Ask the patient to stop breathing, and press Update. The system will freeze automatically at the end of the sweep.
6. If you are happy with the acquisition, press Save 3D Volume. If not, repeat steps 1 through 5.

Coronal transverse

1. Place the transducer on the left side of the abdomen to approach the AAA as close to true coronal plane as possible (Figure 2).
2. Follow steps 2 through 6 as for AP acquisition.

With practice and increasing confidence, you may now find that the patient can leave the examination room. All the measurements can be made from the stored data, on cart or off cart, using QLAB quantification or ViewForum.

Measurement (AP and TS)

1. Open the saved volume data sets, from Review in MPR tab.
2. Measurements will be made from Frame 1, which can be maximized or zoomed to improve caliper placement accuracy.
3. Simply use the Slice rotary control to identify the maximum AAA diameter.
4. Measure AAA diameter using calipers.
5. You may wish to repeat 3 and 4 to take the mean of measurements.

Clinical impact of new volume imaging approach

- Volume ultrasound data sets can be acquired in all patients where 2D imaging of AAA is possible.
- For both AP and TS diameters, there is no significant difference between conventional 2D and volume measurement methods.
- Examination time for volume ultrasound is significantly reduced (as low as 90 seconds).
- Measurement can be “time and place shifted” away from the examination table. For example, in our one-stop AAA clinic, measurements can be made off cart while the patient is returning to see the surgeon, and while the next patient is being scanned. This leads to significant benefits for workflow efficiency.
- Volume data sets are stored for audit and clinical review at next attendance, just as in CT and MR imaging.

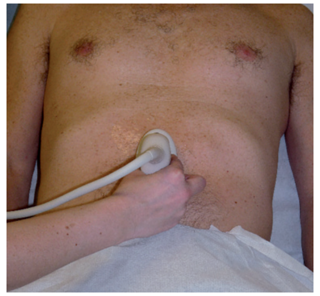


Figure 1

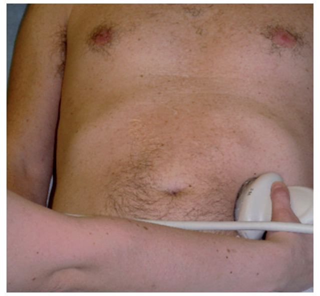


Figure 2

[1] Nyhsen CM, Elliott ST. Rapid Assessment of Abdominal Aortic Aneurysm by 3-Dimensional Ultrasonography, *Journal of Ultrasound in Medicine*. 2006. 26: 223-226

Case Study

A typical example of an AAA surveillance scan using volume acquisition ultrasound.

A 70-year-old female patient with a 4.5 cm infrarenal AAA, undergoing six-monthly surveillance. The previous scans, using conventional 2D method, showed an average examination time (to assess aortic diameter) of approximately five minutes. The volume acquisition method involved an examination time of less than 90 seconds. The measurement was then made from the volume data set, while the patient returned to the referring surgical clinic. The results were typed directly into the RIS system and available to the surgeon immediately.

This practice of using volume ultrasound has led us to redesign our workflow and improve efficiency. In addition, the data sets can be stored for review of measurement technique and caliper placement, particularly for difficult aneurysm configurations, such as a tortuous aorta. This practice further reduces inter-observer variations in surveillance scanning.

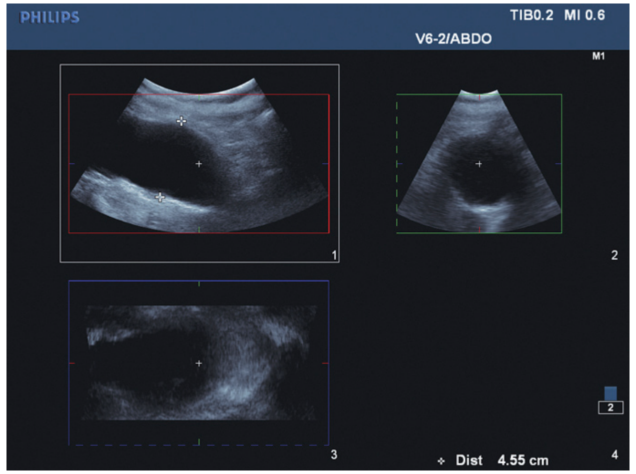


Image A. Longitudinal measurement of maximum anteroposterior aortic diameter from volume data set.

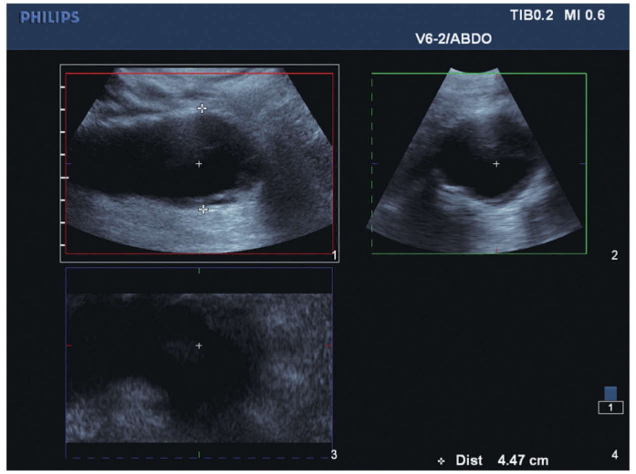


Image B. Coronal measurement of maximum transverse aortic diameter from volume data set.

2. Volume imaging of the gallbladder

Simon T. Elliott, MD
Freeman Hospital, Newcastle upon Tyne, UK

Key reasons to consider 2D plus volume imaging approach

Ultrasound is the first-line imaging modality for suspected gallbladder (GB) pathology. Conventional 2D ultrasound requires meticulous attention to coverage of the whole of the GB using individual, user-selected slice planes. Only those planes are stored for review or second reading.

Volume ultrasound enables capture of the whole of the GB in one or two short sweeps. As in CT and MRI, the dataset can then be reviewed in several planes. The size, location and high tissue-contrast nature of the GB lends itself to this method.

In our unit[2] we have recently shown that volume ultrasound of the GB, using two data sets (supine and decubitus) is as accurate as conventional 2D ultrasound for a range of pathologies, but offers significant advantages in terms of review, audit and time saving. In addition, GB function studies can be performed using volume ultrasound, with greater volumetric accuracy and with much greater efficiency.

How we do the exam

The volume ultrasound examination consists of two sweeps of the GB patient in supine and in left decubitus positions. For both positions the acquisition technique is the same.

1. Using the V6-2 transducer, locate the GB as for conventional 2D scanning.
2. Optimize the image for size, tissue contrast (for example, using harmonics) and resolution (Res/Gen/Pen). Use the highest resolution possible.
3. Align the A-plane (the basic 2D scan plane) with the midline of the long axis of GB, usually from the neck to the fundus.
4. Select 3D/4D menu. You may wish to use the ROI function in this menu to concentrate the sweep to the GB only.
5. Select an appropriate sweep angle. This angle will depend on the size and depth of the GB in each patient, but is usually around 40 degrees.
6. In suspended respiration, start 3D sweep. During the sweep you will be able to see if the entire GB has been included in the dataset. If not, repeat using a larger sweep angle. (Note that the larger the angle, the slower the sweep and the more chance of motion artifact.)
7. Press Save 3D Volume to store.
8. Review data using MPR.
9. Volume rendering mode and QLAB iSlice provide good presentational tools to the referring clinician.

Clinical impact of new volume imaging approach

- Volume ultrasound of the GB can be performed in almost all patients in whom conventional 2D ultrasound is possible.
- Volume ultrasound acquisition is quicker than 2D, leading to efficiency gains.
- Volume ultrasound of the GB can be used as a stand-alone technique for assessing common GB pathologies, such as calculus, clinically significant polyps and cholecystitis.
- The stored dataset provides a permanent record of the entire organ, for second reading, review or audit.

[2] Stenberg B. 3D Ultrasound and its role in abdominal protocols with respect to gallbladder pathology – an empirical study. MD Thesis. 2008. University of Leeds, UK.

Case Study

A 72-year-old male presented with epigastric pain. Conventional 2D ultrasound diagnosed the presence of a small gallbladder polyp. Volume ultrasound confirmed the presence of a single polypoid lesion on the A-plane, but unlike typical gallbladder polyps this was not reproduced on other planes. By using MPR iSlice function, it was suspected that this lesion actually represented a cross section of a linear mucosal structure in the gallbladder. Volume rendering was performed to confirm the presence of a mucosal fold, and that no polyp was present. All this image manipulation was performed, and the final diagnosis made, after the patient had left the examination room, at the time of second reading of the scans.

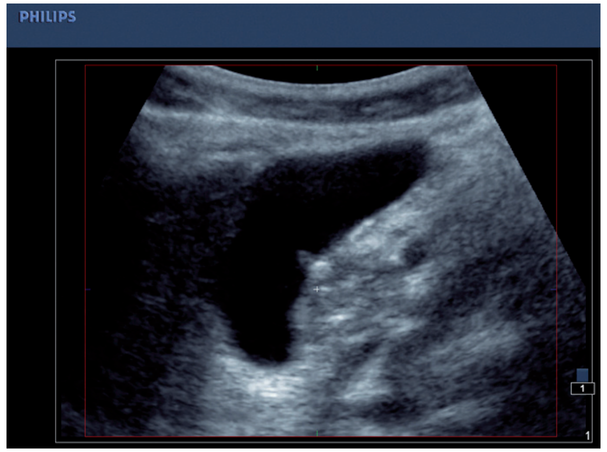


Image A. 2D A-plane scan suggesting gallbladder polyp.

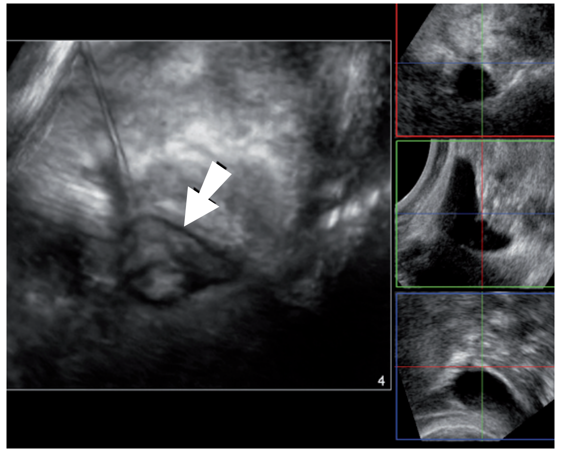


Image B. Volume render showing mucosal fold (arrow).

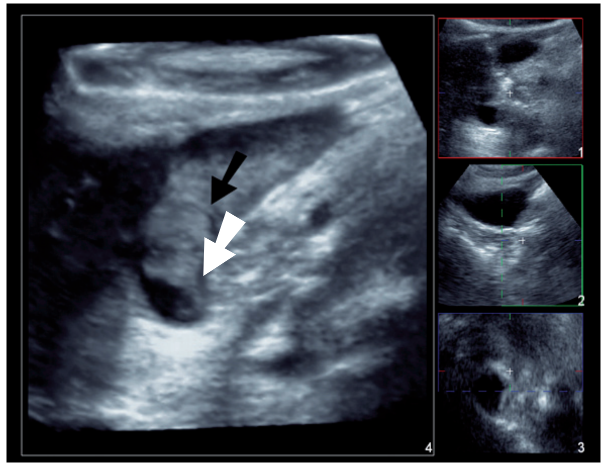


Image C. Volume render showing mucosal fold (arrow).

3. Volume imaging of the gallbladder

Nitin Chaubal, MD
Thane Ultrasound Centre, Thane, Maharashtra, India

Key reasons to consider 2D plus volume imaging approach

In the era of laparoscopic surgery, images of gallbladder pathologies obtained in conventional single planes on ultrasound may provide inadequate information for a surgeon. Ultrasound volumetric imaging for gallbladder has the potential to provide accurate information of gallbladder pathologies both in terms of nature and location of the lesion.

Functional studies of the gallbladder were previously done with 2D ultrasound, providing only rough measurements. Estimation of volume with the 2D technique has serious limitations, depending on the shape of the gallbladder. Volumetric measurement gives more exact volume in pre- and post-prandial status and, hence, is a more accurate way of studying gallbladder function.

Gallbladder volume and wall thickness are also clinically important in deciding the nature of surgery: laparoscopic vs. open. These measurements are now possible with volumetric imaging.

The advantages of volumetric imaging include the abilities to quickly obtain data, store, retrieve, and manipulate it at a later date and at a different site.

How we do the exam

1. Exams are done in fasting state using a V6-2 transducer. Studies are also done after a fatty meal to study post-prandial contraction.
2. Volume sweeps of the gallbladder are taken with patient in decubitus position.
3. Gallbladder is imaged along its longitudinal axis with optimized grayscale and region of interest.
4. Sweeps are also obtained in supine position. (For a few patients in the study, data was obtained with the patient in sitting position.)
5. Once entire gall bladder is included in the dataset, data is stored with 3D volume store.
6. A majority of calculations and reviews can be done afterwards on the ultrasound system and offline using QLAB quantification software on a laptop.

Clinical impact of new volume imaging approach

- Referring clinicians were most impressed with the images and virtual tour of the gallbladder. Moreover, volume imaging helped them in making clinical decisions regarding management and type of surgical approach.
- Functional studies were accurate and useful.
- Studies were timesaving, allowing the ability to review data at later date.
- Difficult regions of gallbladder were studied with ease.

Case Study

A 24-year-old male patient presented with vague abdominal pain. A 2D ultrasound revealed a normal appearing gallbladder with an adjacent part showing thick walls with sludge and calculi. The impression was that of a septate gallbladder.

Volume sweeps of the gallbladder with the V6-2 transducer with 3D reconstruction demonstrated two distinct gallbladder lumens with separate walls.

The images were suggestive of a duplication of gallbladder; this possibility was suggested in the report. Surgery confirmed a duplication of gallbladder, a rare entity. One was normal and the other showed thick walls with sludge and calculi.

Volumetric imaging of the gallbladder helped make this difficult diagnosis. Moreover, this diagnosis was made at the time of reporting, after the patient had left the clinic.

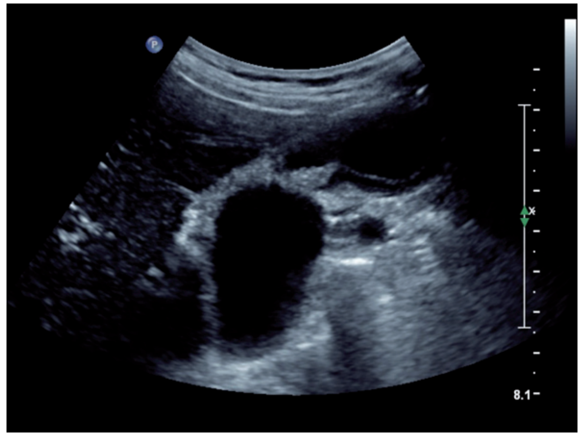


Image A. Suggestion of septate gallbladder on 2D ultrasound.

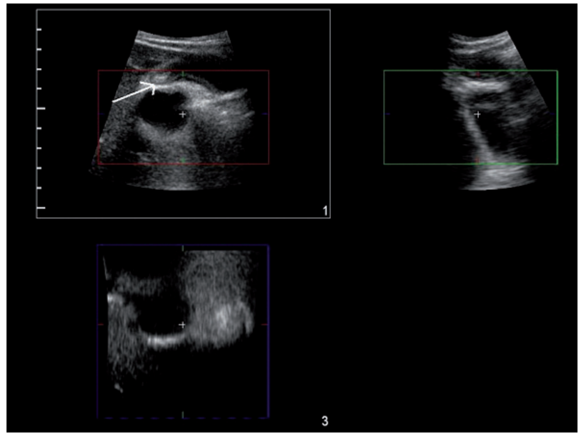


Image B. Volume render.

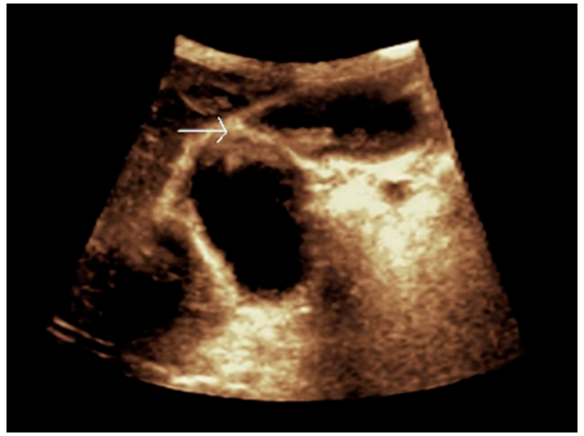


Image C. Volume render with suggestion of duplicated gallbladder.

4. Volume imaging of the kidney

Simon T. Elliott, MD
Freeman Hospital, Newcastle upon Tyne, UK

Key reasons to consider 2D plus volume imaging approach

Ultrasound is a first-line imaging modality for suspected renal pathology. Volume ultrasound can capture the whole of both kidneys in the majority of patients. The data set can be stored for second reading, and reviewed in several planes, as with CT and MRI. Ultrasound image planes that are impossible to obtain using 2D imaging can be produced.

Rotation of the volume data around set pivot points allows a systematic assessment of the renal architecture, particularly the collecting system. Surveillance of renal lesions, such as complex cysts, is improved due to permanent storage of the volume data set, and the high spatial resolution provided by ultrasound.

Volume ultrasound appears to be a more robust and accurate method of measuring renal length.

How we do the exam

Volume ultrasound acquisition is based on the conventional 2D longitudinal view of each kidney. In order to reduce motion artifact and improve visualization of the entire kidney, volume sweeps should be performed in full and suspended inspiration.

1. Using the V6-2 transducer, locate the kidney as for conventional 2D scanning.
2. Optimize the image for size, tissue contrast (for example, using harmonics) and resolution (Res/Gen/Pen). Use the highest resolution possible.
3. Align the A-plane (the basic 2D scan plane) with the midline of the long axis of kidney from pole to pole.
4. Select 3D/4D menu. You may wish to use the ROI function in this menu to concentrate the sweep to a specific region of the kidney.
5. Select an appropriate sweep angle. This will depend on the size and depth of the kidney in each patient, but is usually around 40 degrees.
6. In suspended respiration, start 3D sweep. During the sweep you will be able to see if the entire target has been included in the data set. If not, repeat using a larger sweep angle. (Note that the larger the angle, the slower the sweep and the more chance of motion artifact.)
7. Press Save 3D Volume to store.
8. Review data using MPR.

Measure renal length

1. Acquire as above.
2. In MPR mode, use the A-plane (which should be displaying the longitudinal view of the kidney) for adjustment and measurement.
3. Rotate Z-axis control until the kidney lies roughly horizontal on the image.
4. Rotate the Slice control until you can clearly define the lower pole of the kidney.
5. Drag the MPR crosshair to the tip of the lower pole. Rotate the kidney image around this point by turning the Y-axis control, until the maximum renal length is displayed.
6. Measure the renal length, pole to pole, using conventional calipers.

Clinical impact of new volume imaging approach

- The stored volume data set provides a permanent record of the kidney or focal lesion, for second reading, review, or audit. This is particularly useful for surveillance scanning.
- Volume ultrasound offers a more systematic and controlled review of renal architecture.
- Measurement of renal length is more robust and potentially more accurate.

Case Study

A 31-year-old male patient with a previous history of matrix renal calculi, attended for ultrasound examination of the kidneys. 2D ultrasound showed a normal left kidney and a mild right hydronephrosis. Definition of the collecting system was, however, poor (Image A), and there was the suggestion of a matrix calculus within the lower pole calyces (Image B). A single volume acquisition scan was performed on the right kidney. By placing the MPR crosshair over the renal pelvis, and rotating around this pivot point using the Y-axis control, it was possible to interrogate systematically each part of the collecting system (Images C and D).

The views obtained were significantly better than using 2D ultrasound, enabling the operator and second reader to confirm that, other than the mild hydronephrosis, the kidney was normal and that no renal calculus was present.

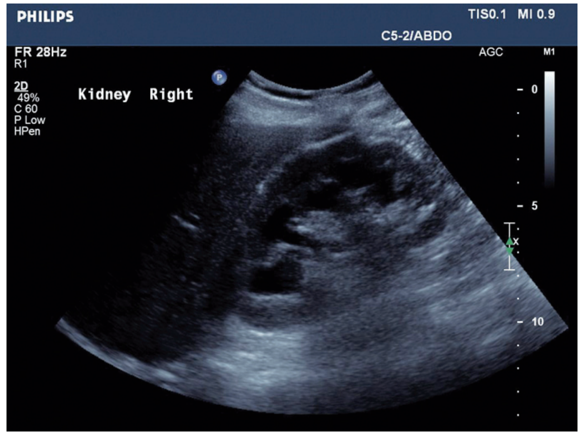


Image A. Poor definition of collecting system using 2D ultrasound.

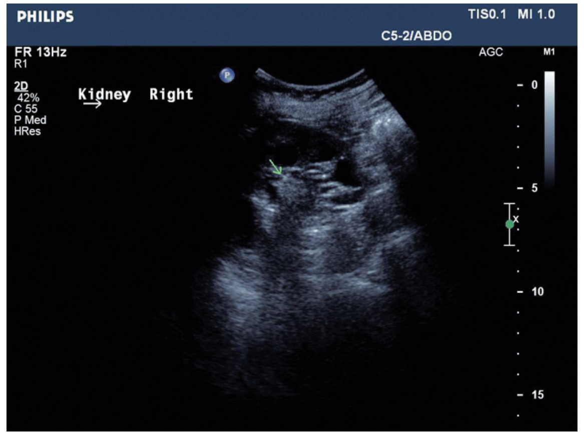


Image B. Possible matrix calculus with 2D ultrasound.

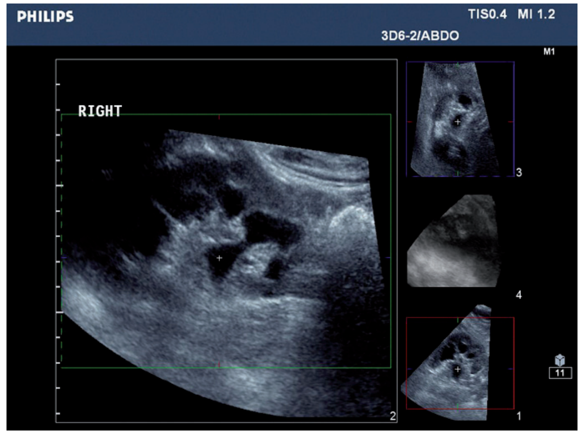


Image C. Volume ultrasound showing lower pole calyces.

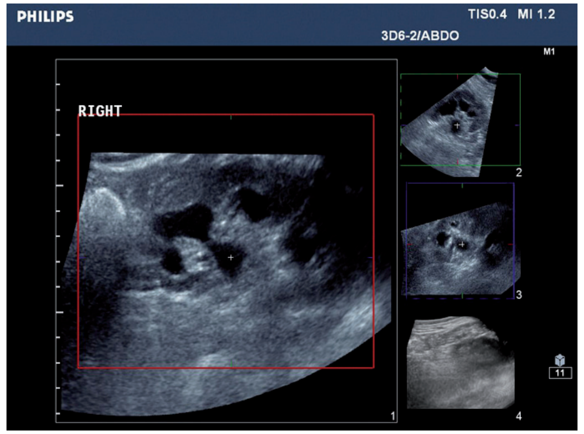


Image D. Volume ultrasound showing upper pole calyces.

5. Volume imaging of the kidney

Nitin Chaubal, MD
Thane Ultrasound Centre, Thane, Maharashtra, India

Key reasons to consider 2D plus volume imaging approach

Volume measurements of kidneys have potential benefits in nephrology. As compared to linear measurements on 2D, volume is more useful and accurate in following up patients.

Volume measurement of transplanted kidneys on a baseline scan is also useful in picking up early rejection.

Volume ultrasound gives anatomical details of the pelvicalyceal system as never seen before; this has potential for evaluating intrinsic lesions in the collecting system.

Volume imaging with power Doppler has the potential to demonstrate the exact relationship of tumors with surrounding vessels, which is useful in planning organ-saving surgery.

Reconstruction and measurements can be performed offline and data stored.

How we do the exam

Examination is performed with patient in lateral decubitus position, using the right lobe of liver as a window on the right side.

1. Using the V6-2 transducer, a sagittal section is obtained, making sure cortex is symmetrical on either pole.
2. Image optimized, region of interest optimized, central line aligned along long axis of kidney, patient made to stop breathing and sweep obtained. 3D volume data stored.
3. Reconstruction, volume measurements done offline.

Clinical impact of new volume imaging approach

- Stored volume data is useful for comparison of renal volume when patients came for follow up in nephrology and transplant outpatient departments.
- Improved demonstration of anatomical details of lesions within pelvicalyceal system and renal masses in relation to renal vessels.

Case Study

A 43-year-old female patient with a previous history of renal calculi attended for ultrasound examination of the kidneys. 2D ultrasound showed a normal left kidney. There was a suggestion of multiple calculi within the pelvis of right kidney (Image A). A single volume acquisition scan was performed on the right kidney. By placing the MPR crosshair over the renal pelvis, it was possible to interrogate the pelvis with calculi (Image B).

The views obtained after reconstructions were significantly better than using 2D ultrasound and showed a staghorn calculus, and not multiple calculi, as was the impression provided by 2D ultrasound (Image C). The staghorn calculus was also confirmed on digital X-ray (Image D).

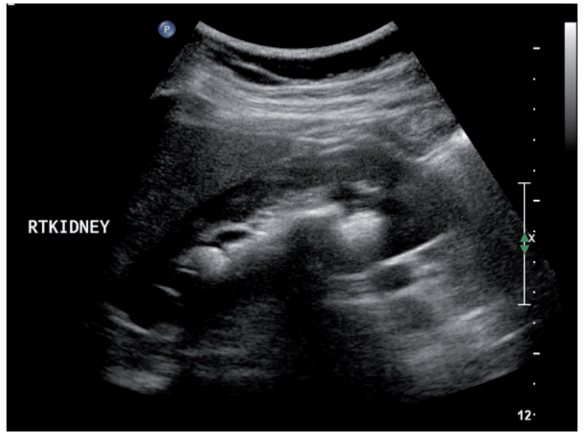


Image A. 2D ultrasound suggestive of multiple calculi.

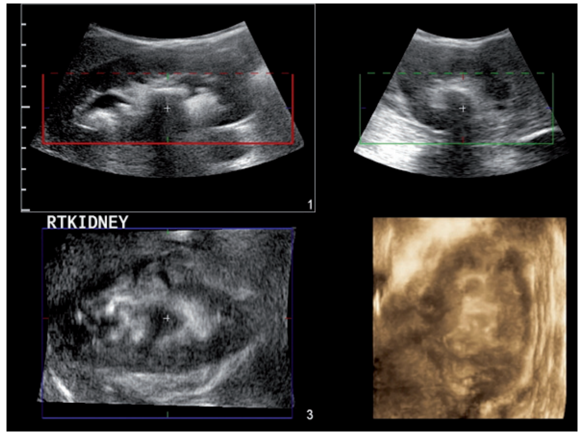


Image B. Volume ultrasound.


Image C. Reconstruction with QLAB confirming staghorn calculus.

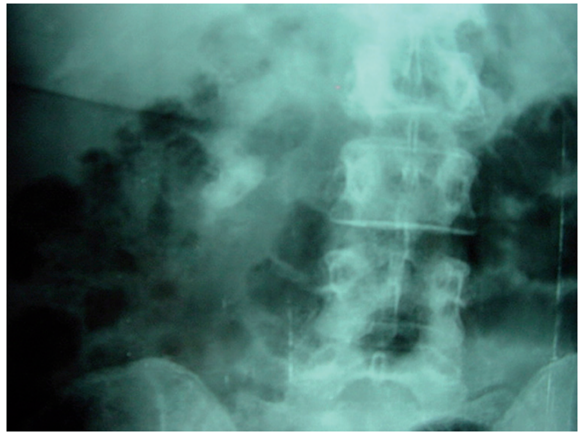


Image D. The staghorn calculus was confirmed on X-ray.

6. Volume imaging of the kidney

Michel Claudon, MD
Centre Hospitalier Universitaire, Nancy, France

Key reason to consider 2D plus volume imaging approach

Demonstration of the extension of a tumor within the renal vein and vena cava is better provided by 3D imaging than by 2D imaging. Post-treatment capabilities in this case are based on MIP-like images, with plane and thickness adapted to the anatomy of the studied case.

How we do the exam

1. After the 2D evaluation, use the V6-2 MHz transducer.
2. Find the best acoustic window using a posterior and lateral approach to the right kidney, and scan the kidney and the tumor on a long axis.
3. Use harmonic imaging, optimize depth, gain and focus.
4. Select the adequate sector angle to cover the tumor and the venous extension (here 55 degrees), and try to anticipate the patient breathing to minimize motion artifact.
5. Use the thick slice mode (24 mm) in the QLAB post-treatment.

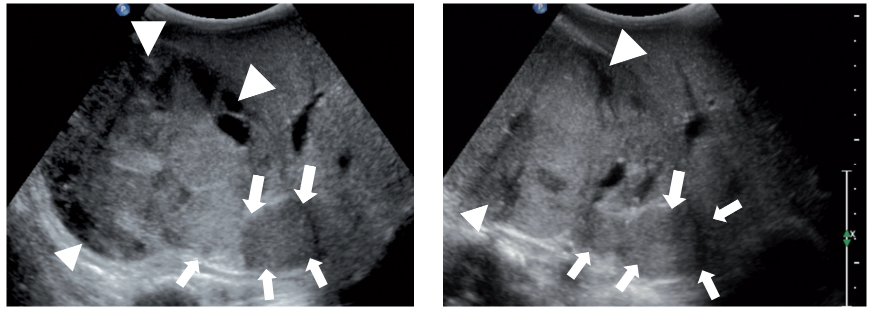
Clinical impact of new volume imaging approach

Precise evaluation of a renal tumor and demonstration of extension into the draining venous system obtained with 3D imaging at the first diagnostic step, before CT or MRI examinations.

Case Study

A two-year-old male, presenting with a right abdominal mass. Ultrasound reveals a large mass (diameter = 10 cm) developed from the right kidney, suggestive of a nephroblastoma. A neoplastic extension to the renal vein and the inferior vena cava was seen on 2D sweeps.

However, 3D imaging much more clearly demonstrated the shape of the venous extension and its upper limit, which remains below the diaphragmatic level, as confirmed on the subsequent CT scan.



Images A and B. Grayscale 2D transverse and oblique views show the tumor (arrowheads) and demonstrate a tumor extension to the renal vein and the vena cava (arrows).

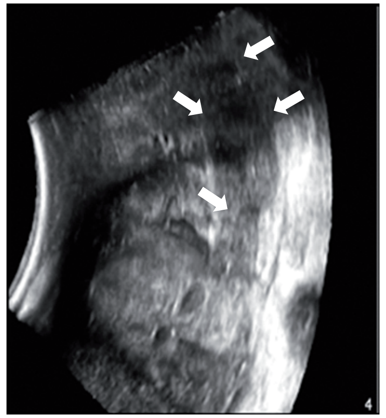


Image C. 3D imaging. A coronal thick slice nicely shows the venous extension up within the upper vena cava (arrows).

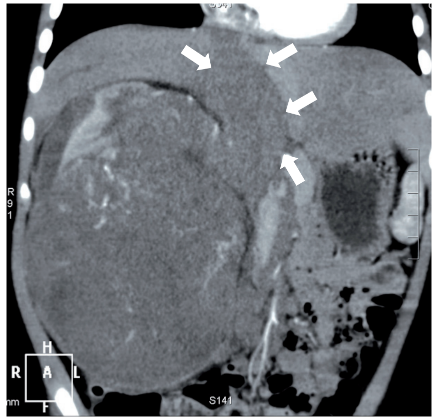


Image D. CT scan coronal reformation confirms the 3D ultrasound imaging findings.

7. Volume imaging of the liver

Etienne Danse, MD, PhD
Mohamed Kichouh, sonographer
St. Luc University Hospital, Université Catholique de Louvain, UCL, Brussels, Belgium

Key reasons to consider 2D plus volume imaging approach

Despite the improvement of CT and MRI, sonography is still considered a first-line imaging method for evaluation of the liver. It is also contributive for the follow-up of chronic liver diseases (post-viral hepatitis, cirrhosis), for the detection of signs of portal hypertension, assessment of portal vein patency, and for the detection of possible hepatocarcinoma. Sonography also plays a role for the follow-up of liver transplantation and after transjugular intrahepatic portosystemic stent (TIPSS) procedures.

Based on at least one year of routine use of a volumetric transducer, 2D combined with volume imaging has contributed to optimizing our sonographic findings.

How we do the exam

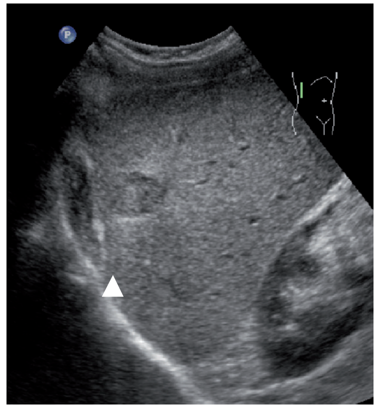
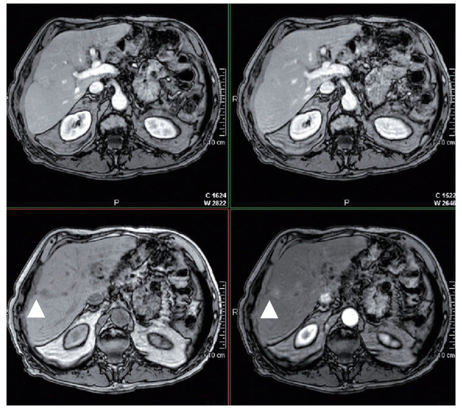
1. Perform the liver investigation as usual, initially without volumetric acquisition, with the C5-1 or C5-2 transducer.
2. When a lesion or an anatomical variant appears during the sweeps, do at least two perpendicular volume acquisitions centered on the considered lesion with the V6-2 transducer, in the supine and left lateral decubitus positions.
3. Check the touchscreen of the iU22 system to be sure that all the area to investigate is included in the volume set.
4. Send these volumetric sets to the PC workstation equipped with QLAB software. These volume sets can be analyzed during the reporting time, when the patient has already left the practice room.

Clinical impact of new volume imaging approach

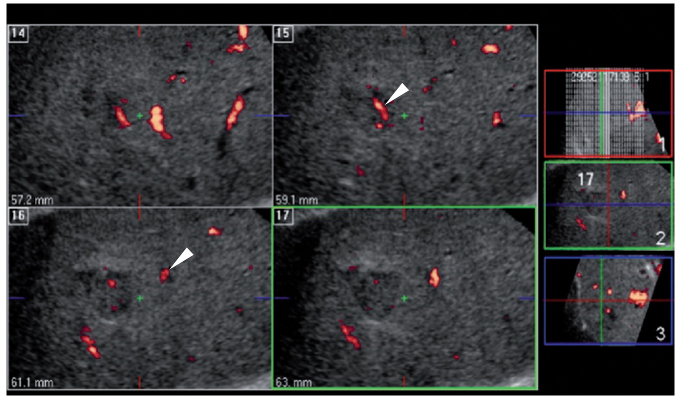
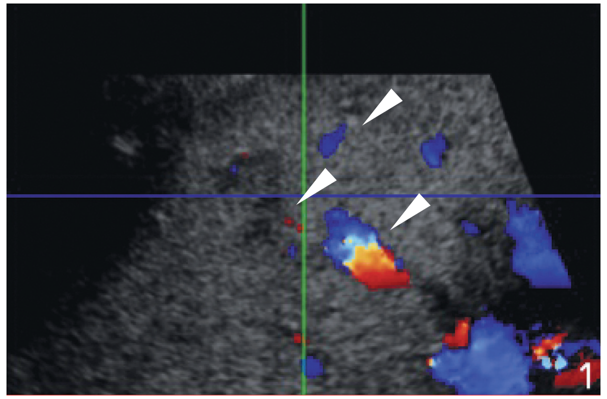
- The main contribution of adding volume acquisitions during liver scanning is better confidence for the location of a liver mass combined with lesser time duration of the examination.
- Volumetric acquisitions are then helpful for a better localization of lesions according to the liver segmentation.
- Degree of extension of a mass in the respective segments of the liver is also better evaluated. This contributes to a more precise visualization of vessels close to the lesions, and is then useful for the selection of specific treatments for malignant tumors (guided procedures or by surgery).
- Determination of a liver invasion by a neighboring mass, from the kidney for instance, is also achievable.
- An additional benefit is a better understanding of anatomic variants (both of the liver or its vascular network), allowing reduced misinterpretations and unnecessary additional exams such as CT or MRI.

Case Study 1

This patient has a hepatocarcinoma. Surgery is planned for treatment of this hepatocarcinoma. To aid the surgical approach, ultrasound is required to identify the vessels coming close to the lesion.

Images A and B. The lesion (arrowheads) is visible on B mode with a good correlation with MRI.

Images C and D. Volume acquisition is done for an optimal view of the vascularisation around this lesion, showing the vessels close to the liver lesion. The vessels (arrowheads) are near and within the liver lesion.

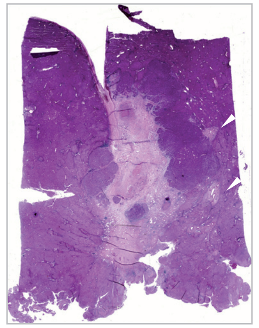


Image E. Correlation between pathology and reformatted sonographic views (the vessels near the lesion are pointed with arrowheads).

Case Study 2

This patient received an ultrasound after endovascular treatment of a hepatocarcinoma (chemoembolisation) in order to plan a liver transplantation. With conventional ultrasound, the extent of the site of treatment was difficult to assess, as well as the visualization of the portal vein near this site. Volume sonography was contributive for a better understanding of the situation.

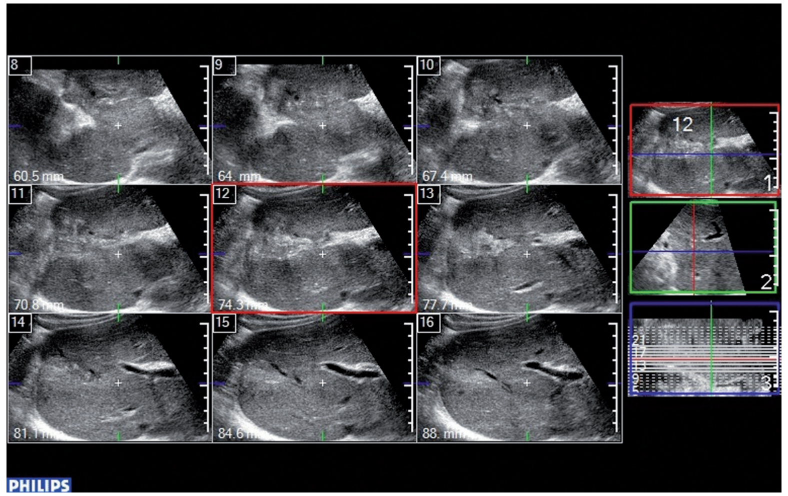


Image A. iSlice screen of one volume set, centered on the site of the lesion.

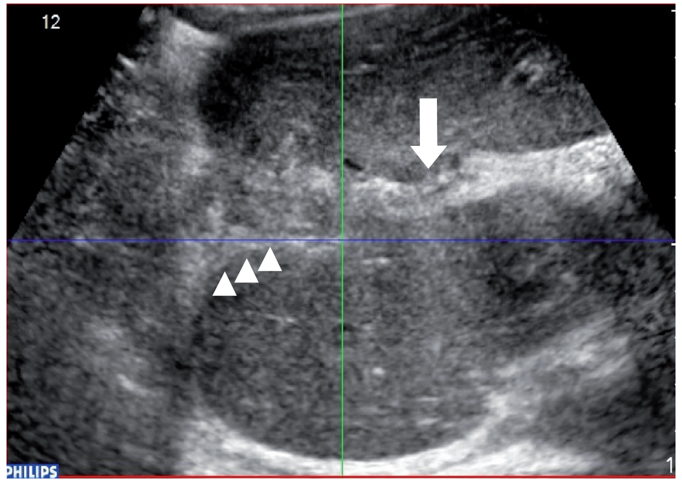


Image B. By rotation of the images on the fourth view (the 3D view), we can better see the site of the lesion (arrowheads), the thrombosed portal vein (arrow) and its connection to the site of the lesion.

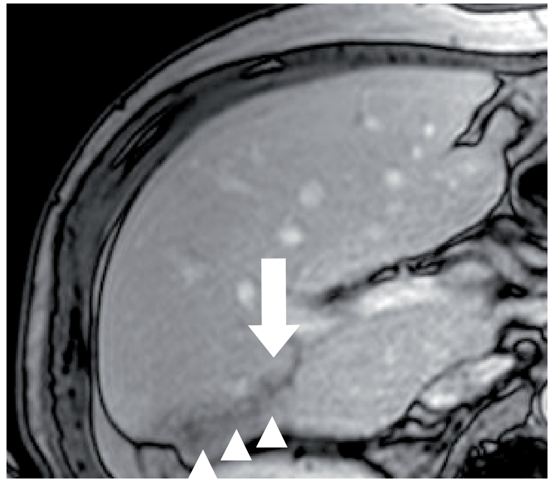


Image C. MRI correlation (examination within the same delay of the ultrasound).

Case Study 3

Sonogram requested for the diagnosis of a liver mass detected during a routine examination. The volume approach was useful, showing the feeding vessel, which gave more confidence for the final diagnosis of focal nodular hyperplasia (FNH).

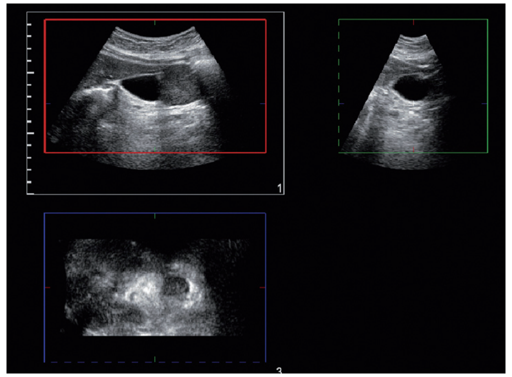


Image A. Volume set acquisition centered on the mass.

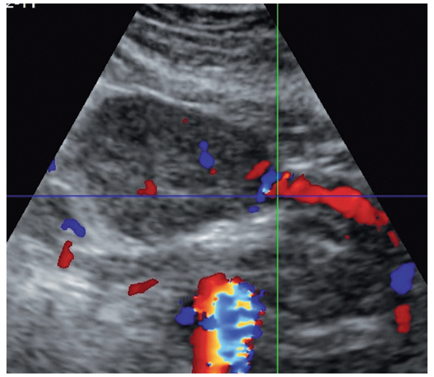
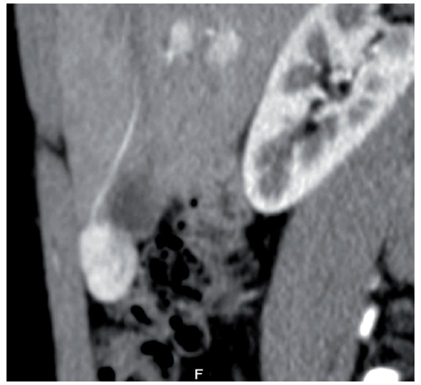
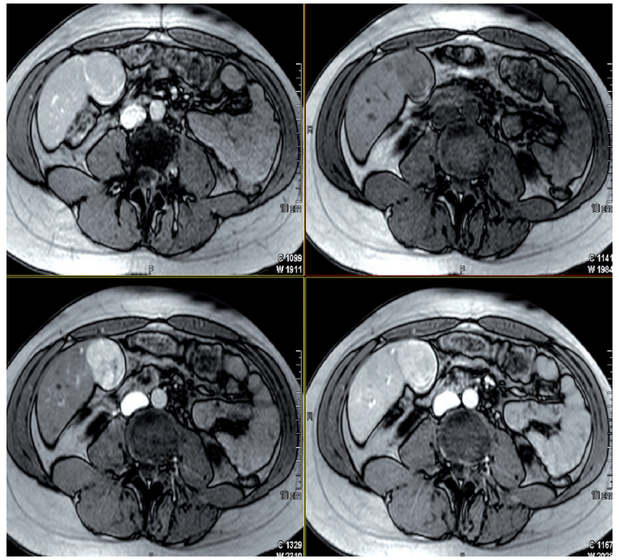


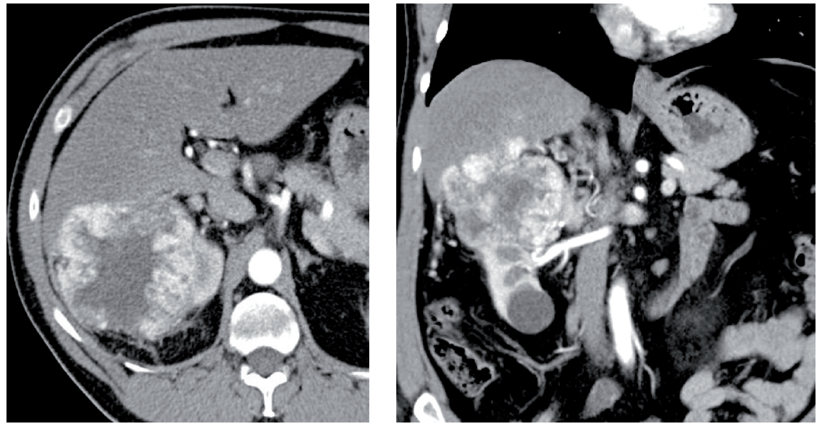
Image B. A reconstructed view based on volume set showing the vascular pedicule of the lesion.



Images C and D. CT and MRI correlations of the FNH.

7. Volume imaging of the liver

Case Study 4

This 55-year-old male is admitted for surgical resection of a huge renal carcinoma. Based on CT and conventional ultrasound, liver invasion by the renal tumor is strongly suspected. Volume ultrasound is required for an answer to this point. Volume acquisitions, by using iSlice, helped the demonstration of an absence of liver invasion by the renal tumor. We concluded an extrinsic compression of the liver parenchyma by the renal mass (surgically confirmed).



Images A and B. Axial and frontal CT reconstructions showing the renal mass and suspected invasion to the liver.

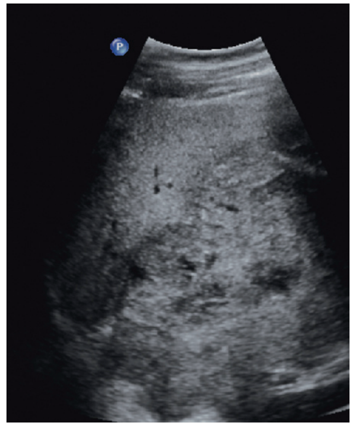


Image C. Conventional sonogram showing the renal mass and absence of separation of the renal mass from the liver.

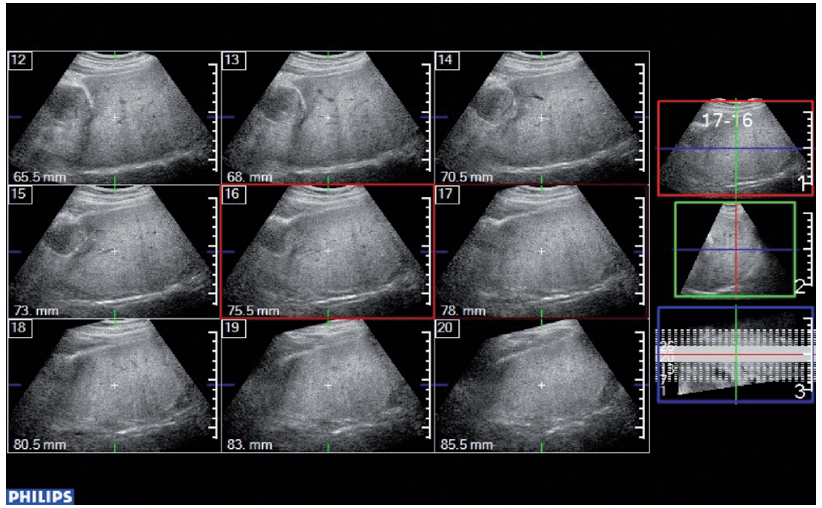


Image D. Volume set acquisition centered on the upper part of the renal mass. With volume imaging, we concluded the absence of liver invasion on iSlice set of images.

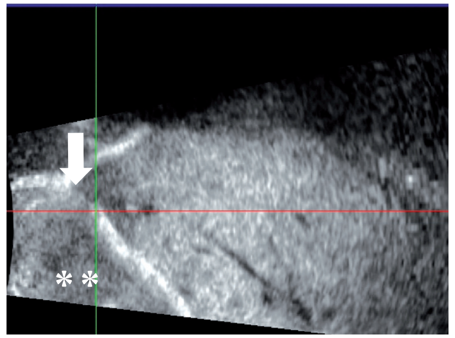


Image E. On this coronal reconstructed view (arrow) the absence of liver invasion was confirmed during surgery (*renal mass).

Case Study 5

A volume approach done in this case of follow-up of chronic hepatitis was contributive to the better understanding of the portal vein anatomy and the detection of an uncommon variant. During conventional sonogram, we note the absence of the left portal vein in its normal location, which could be related to agenesia, old thrombosis, or an anatomical variant. Based on the publication of Atri et al.[3] the portal anatomy was better depicted.

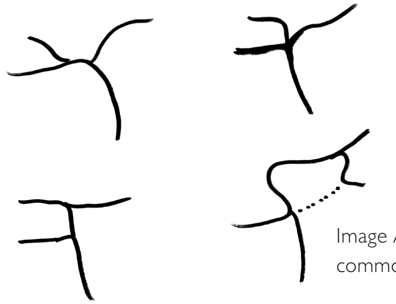


Image A. Drawing of the common portal veins variants.

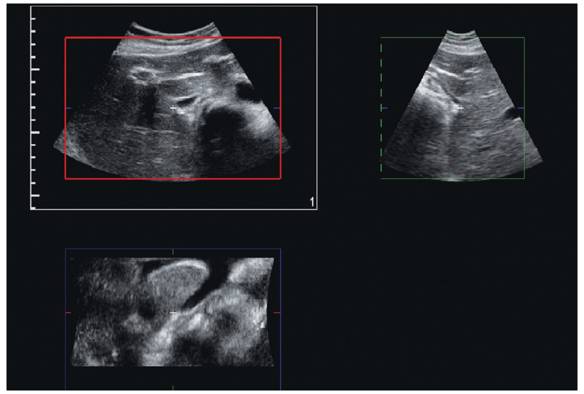


Image B. Volume set at the level of segment 1 and the portal bifurcation.

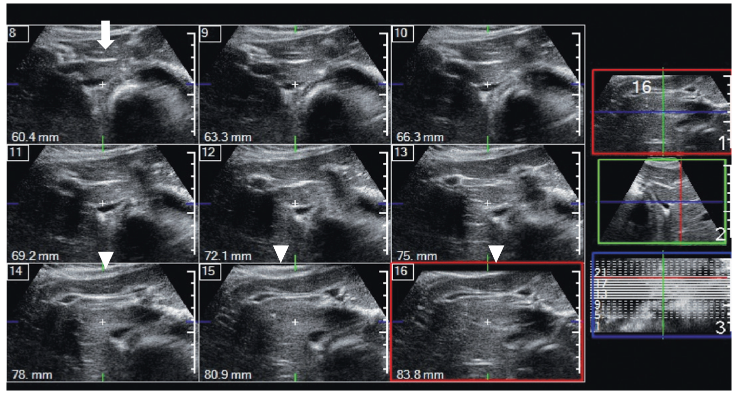
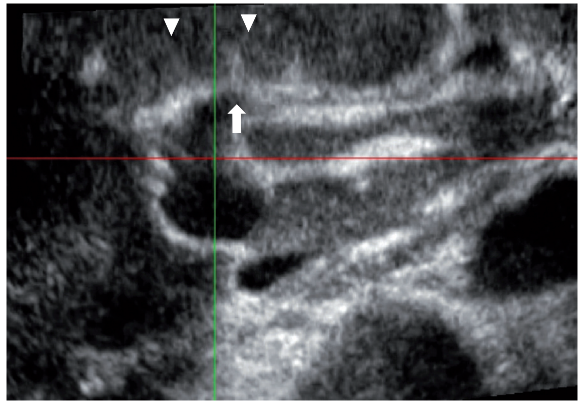
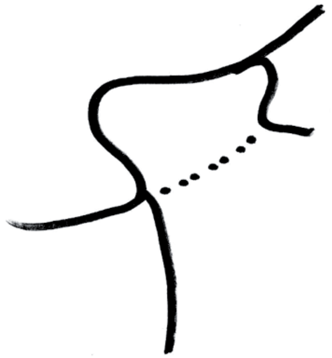


Image C. iSlice view of a volume set at the level of segment 1 and the portal bifurcation. We note the absence of the left portal vein at its normal location (arrow). This left trunk is upper located, within the liver parenchyma (arrowheads).





Images D and E. Frontal reconstruction on B mode showing the absence of the normal left portal vein (arrow) and the variant of its location (arrowhead), with schematic correlation.

[3] Intrahepatic portal variations: prevalence with US, *Radiology*, 1992, 184,:157-158

7. Volume imaging of the liver

Case Study 6

This sonogram was done during the follow-up of cirrhosis. Volume acquisition gave us the opportunity for a better illustration of recanalyzed paraumbilical veins, difficult to show on conventional images and not visible on previous examinations.

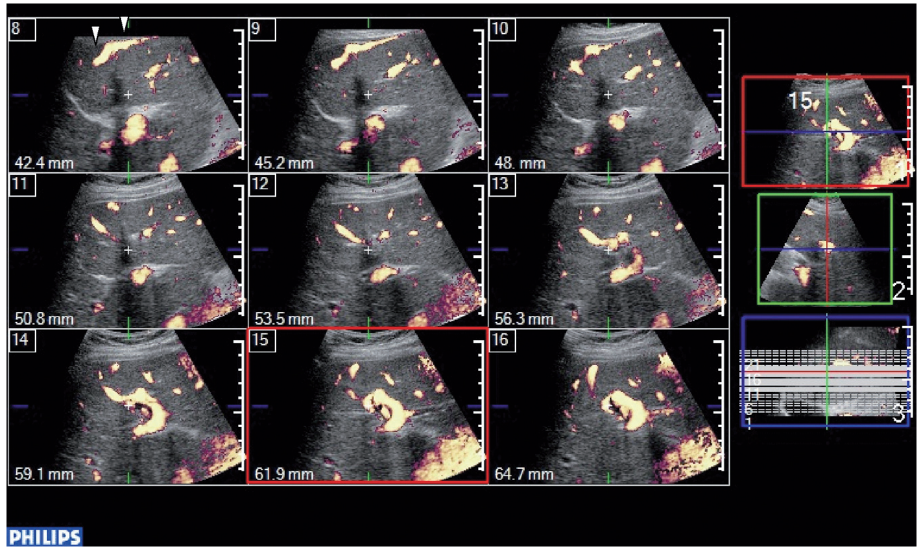


Image A. iSlice screen showing one paraumbilical vein, only partially (arrowhead).

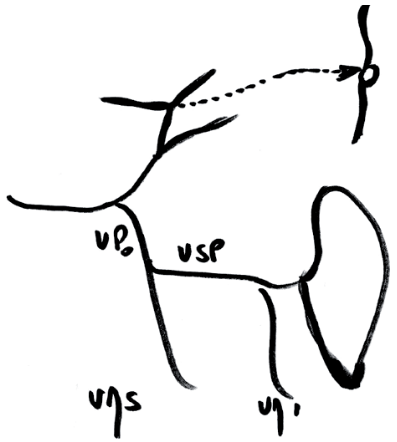


Image B. Drawing of common recanalyzed paraumbilical veins visible with ultrasound.

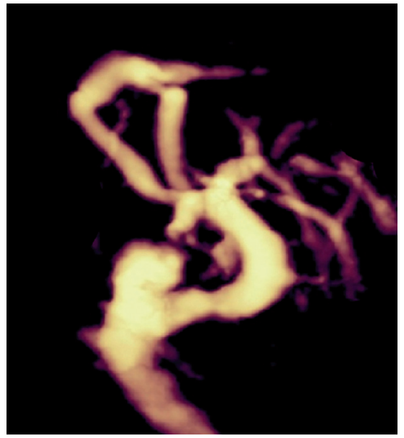


Image C[4]: Volumetric reconstruction showing two paraumbilical veins coming from the « Rex » recessus.

[4] Adapted from Lafortune et al, AJR 1985, 144:549-553, The recanalized umbilical vein in portal hypertension: a myth.

8. Volume imaging of the liver

Stephanie R. Wilson, MD
University of Calgary, Calgary, Canada

Key reasons to consider 2D plus volume imaging approach

The liver is the largest organ in the body and it varies considerably in size and shape among individuals. The liver is located high in the abdominal cavity and deep to the rib cage. Several factors serve as challenges to the acquisition of good hepatic volumes including sensitivity to movement artifact from both respiration and from cardiac activity. Furthermore, common liver pathologies, such as cirrhosis and steatosis, may disrupt the normal liver parenchyma and size such that adequate access and penetration may be problematic.

Despite the potential obstacles to volumetric acquisition of liver data, techniques for performance of hepatic volumetric acquisitions may provide good data showing liver parenchyma, vasculature, and pathology.

How we do the exam

1. As with all volumetric scans, we follow a defined protocol which starts with a prescan. The prescan should determine the optimal placement of the transducer, the optimal phase of respiration for breathhold, the optimal focal zone and placement, and the optimal patient position: supine or left lateral decubitus.
2. The optimal plane for acquisition is generally in the long axis of the right and left portal veins as they arise from the main portal vein at the porta hepatis. This plane is easily achieved in most patients with a subcostal oblique transducer placement with angulation towards the right shoulder.
3. Acquisition is performed with suspended respiration, usually at full inspiration. This will generally show the hepatic venous confluence at one extreme of the volume and the structures of the hepatoduodenal ligament at the other extreme, as the acquisition essentially encompasses the entire organ in a single sweep.

In summary, the prescan determines:

- Choice of transducer frequency – generally, standard for abdomen
- Choice of transducer design – curved
- Choice of optimal plane for acquisition – subcostal oblique through plane of the portal venous confluence at the porta hepatis
- Choice of optimal acquisition technique – generally, mechanical
- Choice of optimal phase of respiration – generally, suspend in /' full inspiration

Difficult acoustic windows, small cirrhotic livers, very large liver masses, fatty liver, and obesity all compromise the success of this technique.

Clinical impact of new volume imaging approach

In our study at the University of Calgary consisting of 200 consecutive patients, successful liver volumes were obtained on the majority of patients, with documented failures related to end-stage cirrhosis and obesity. In our experience, liver status (normal, cirrhotic, or fatty) is accurately assessed on a single volume in the majority of patients. Focal liver masses and their relationship to the vital vascular structures are also well demonstrated with a three-dimensional technique.

- Appreciation of the normalcy or abnormalcy of the liver is optimally determined on a volumetric acquisition. Liver size, contour, lobar distribution, and echotexture can all be shown in a single sweep (Image A).
- In patients with focal disease, a good acquisition shows the number, distribution, and morphology of lesions, often reducing the necessity for hands-on review of the pathology by the physician.
- In the patient with potential surgical disease, the relationship of pathology with the vital vascular structures in the liver can be optimally shown on a volumetric multi-planar reconstruction (MPR) series of images (Image B).

8. Volume imaging of the liver

Case Study 1

A normal liver in an asymptomatic young female is shown in a nine-on-one stacked format in the acquisition A plane. The center image is the starting point for the subcostal oblique acquisition, and it shows the long axis of the right and left portal veins at their origin from the main portal vein. The image (top left) shows the structures of the portal triad within the hepatoduodenal ligament at the caudal border of the liver. The bottom three images all show the hepatic venous confluence at the inferior vena cava and the cephalad border of the liver. Therefore, a single such acquisition shows virtually the entire liver and its vascular structures.

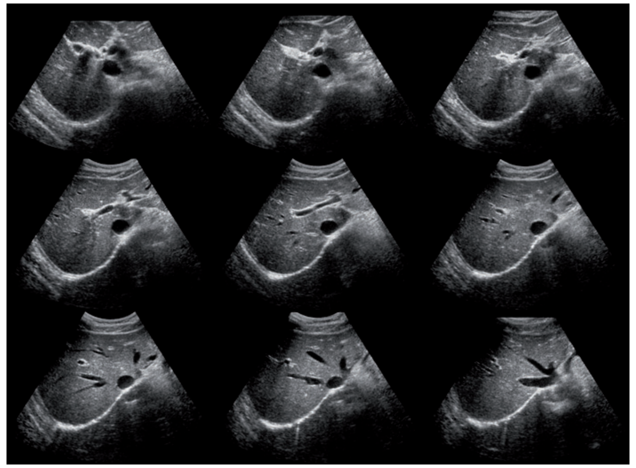


Image A. Nine-on-one stacked format in the axial plane of a normal liver.

Case Study 2

A 58-year-old male with known colorectal cancer is scanned to determine resectability of a suspect liver metastasis. A multiplanar reconstruction shows the liver mass within a large fatty liver in the acquisition A plane (left) in the long axis B plane (top right) and in the coronal C plane (bottom right). The close proximity of the segment 8 mass to the middle hepatic vein is shown with clarity on the A and C plane images. The volume data provides information about the size and texture of the background liver. It is both large and fatty and,in addition, it shows the solitary and large tumor mass with its relationship to vital vascular structures.

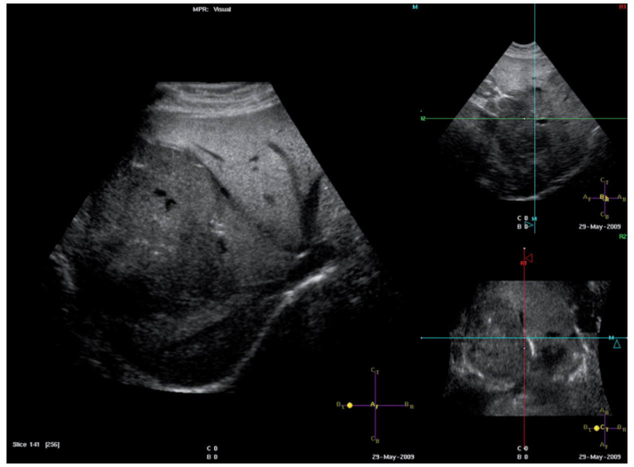


Image B. A multiplanar reconstruction shows a large right lobe liver metastasis in all three planes.

9. Volume imaging of the bowel

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Thane Ultrasound Centre, Thane, Maharashtra, India

Key reasons to consider 2D plus volume imaging approach

The advent of high resolution machines and high frequency transducers has made ultrasound imaging of the bowel a reality. While there are still limitations in evaluating intrinsic lesions in the bowel lumen with conventional ultrasound, volumetric imaging has been useful in evaluating intrinsic lesions within the bowel, as well as bowel wall pathologies.

Volumetric imaging has potential to visualize the lumen of bowel just as virtual scopy on CT scan. The rapid collection of data and the ability to analyze data at a later stage are the greatest advantages of volumetric imaging.

How we do the exam

The volume ultrasound of bowel is performed with a V6-2 transducer and an xMATRIX transducer. Unless there is clinical contraindication, like an acute abdomen, hydration of patient helps in evaluation of bowel.

Examination with V6-2 transducer

1. Area of interest was identified with conventional ultrasound using linear 12-5 or linear 9-3 transducers.
2. Area of interest matched with region of interest and volume sweeps obtained.
3. Once satisfactory area covered, volume data stored with volume 3D store.
4. Analysis done with QLAB after patient left the clinic.
5. Threshold used to optimize region of interest.

Examination with xMATRIX transducer

1. Area of interest was identified using linear L12-5 or linear L9-3 transducers.
2. xMATRIX transducer was then used in the area of interest in the Live 3D mode. This setting gives live 3D images of the area of interest.
3. Images were optimized for gray scale and chrome was used.
4. Images were optimized to visualize inside of the bowel lumen.
5. Loops were stored in live capture.

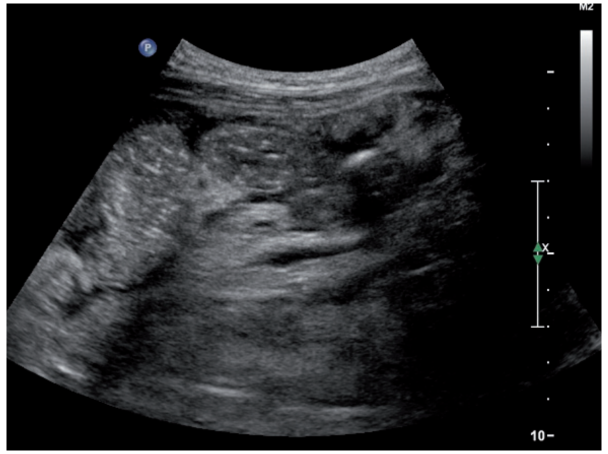

Image A. Poor definition of bowel and mesentery.

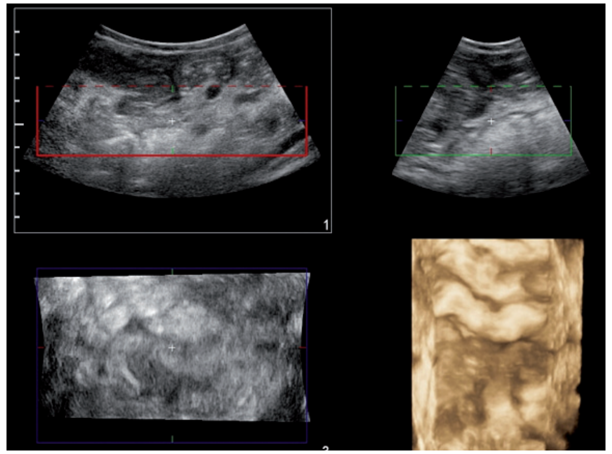

Image B. Volume data with volume ultrasound.

Image C. Analysis with QLAB showing bowel loop with mesenteric thickening clearly.

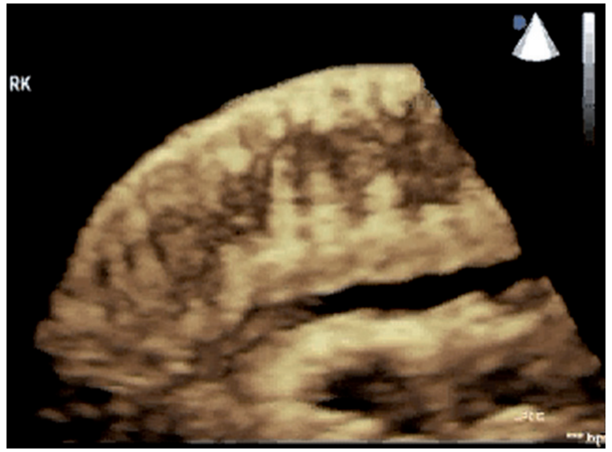

Image D. Intrinsic lumen of bowel on xMATRIX transducer-sonoscopy.

10. Volume imaging of the bowel in patients with Crohn's disease

Stephanie R. Wilson, MD
University of Calgary, Calgary, Canada

Key reasons to consider 2D plus volume imaging approach

Crohn's disease (CD) is the most common form of inflammatory bowel disease (IBD). The peak age of onset is between adolescence and early adult life. With each exacerbation of symptoms, the patient is subject to diagnostic imaging procedures to show the status of the disease.

CD is frequently evaluated with cross sectional imaging techniques, including sonography. The imaging objective is to efficiently show the extent and activity of CD and to detect and characterize any complication. The extent and activity are determined by assessing the classic features of CD, which include gut wall thickening, inflammatory fat, perienteric lymphadenopathy, and hyperemia. The complications include stricture, mechanical bowel obstruction, perforation, fistulization, and inflammatory masses, however they are more difficult to predict and assess.

A CT scan is the most frequent choice to evaluate CD. Considering the young population most often affected, and also the chronic nature of CD, this choice of radiation procedure is untenable. Sonography is shown in multiple publications to be sensitive to the detection of gut wall thickening in CD, and it is also able to identify complications. However, the single frame image display most often used in sonography does not allow the referring clinician to adequately appreciate the pathology that might be shown on a sonogram, especially in patients with significant complications. Furthermore the magnitude of change may be substantial, consequently, neither the relationships nor the complexity can be appreciated without a hands-on evaluation.

A volume acquisition allows for a real-time review of the data in all three planes as well as allowing for multi-planar reconstruction (MPR) of the data to show intricate associations and relationships otherwise impossible with ultrasound. This is a premier application for volume imaging and, in our practice, it surpasses all others. Perhaps in no other area of sonography does volumetric acquisition of data have such a profound impact as in the evaluation of a patient with CD.

How we do the exam

1. A prescan is required to identify the abnormal bowel loops by visualization of the classic features defining CD.
2. Once identified, the choice of the correct transducer frequency is required, often a high-frequency linear or curved transducer.
3. The optimal plane for acquisition is determined and the choice of method of acquisition is chosen. The options include a freehand acquisition, which has the advantage of allowing a longer length of acquisition, or a mechanical acquisition, which makes a smaller volume and suffers from loss of resolution in the perpendicular planes.

The optimal respiratory phase for volume imaging of the bowel is often less critical than for many of the solid organs. However, the bowel is often mobile, and suspended respiration may improve the data acquisition.

In summary, the prescan allows for:

- Choice of transducer frequency – as high as possible
- Choice of transducer design – curved or linear
- Choice of optimal plane for acquisition – often cross section
- Choice of optimal acquisition technique – preference is freehand
- Choice of optimal phase of respiration – generally, suspend in expiration

The volume acquisition is performed with the focal zone set at the midpoint of the bowel lumen, and the field of view set to include several centimeters of soft tissue both superficial and deep to the bowel.

The volume data should then be reviewed for completeness and accuracy. If necessary, additional volumes or AVI acquisitions should be performed to show relevant changes in the bowel activity, exaggerated peristalsis, dysfunctional peristalsis, to-and-fro peristalsis, and blood flow to the abnormal bowel and abnormal soft tissues.

Once pathology is identified, an acquisition volume is often performed in both the long axis and in the cross sectional plane to encompass the entire length of abnormal bowel, with inclusion of the perienteric soft tissues.

Clinical impact of new volume imaging approach

- With utilization of freehand acquisition, volumetric imaging of the bowel is of considerable value, surpassing every other application we have investigated (Image A).
- The presence, extent, and degree of activity of the inflammatory process in the bowel are established (Image B).
- The presence of any complication is shown in relationship to the bowel and surrounding soft tissue.
- Ultrasound with volumetric imaging provides information equivalent to a CT scan without the requirement for ionizing radiation.
- It is available, safe, and easily performed while showing the classic features of Crohn's disease as well as its frequent and significant complications.

10. Volume imaging of the bowel in patients with Crohn's disease

Case Study 1

A 44-year-old female with known Crohn's disease for seven years. Surveillance volume scan acquired in the axial A plane (left) shows thick gut with wall layer preservation. The long axis B plane (right top) shows a long and continuous length of abnormal bowel, providing information about disease extent. The coronal C plane (bottom right) shows both the long segment of involved bowel, and the adjacent echogenic inflamed fat exceptionally well. There is no evidence of complication.

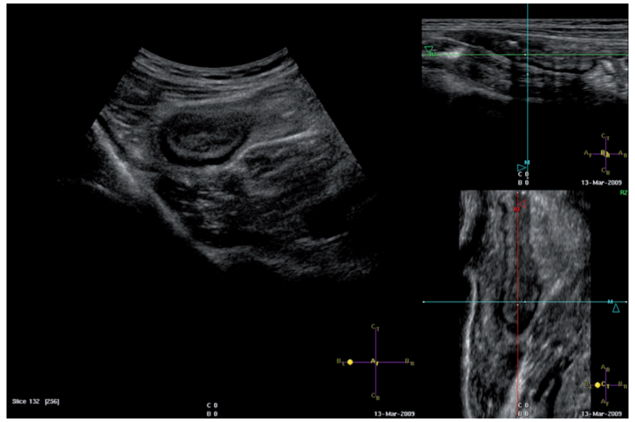

Image A. Uncomplicated long segment Crohn's disease.

Case Study 2

Highly complicated Crohn's disease with microperforation and incomplete mechanical bowel obstruction in a 54-year-old male with known inflammatory bowel disease and recent acute flare of symptoms.

Emergency ultrasound of the right lower quadrant with multiplanar reconstruction shows the acquisition A plane is in the long axis of the abnormal gut (left) and the axial B image (right bottom) with the coronal C view (top right).

The long and continuous length of severely thickened gut shows luminal apposition distally, on the left of the long axis image, with a dilated, air-filled segment proximal, on the right of the long axis view. Intensely inflamed echogenic fat, and a serrated border to the deep edge of the gut, suggests perforation with phlegmon, especially on the long axis and short axis views.

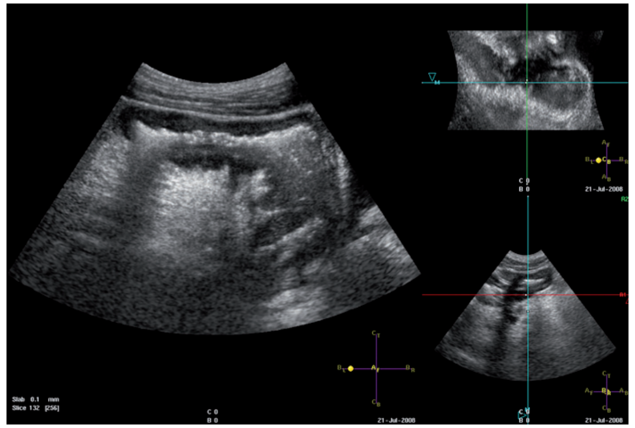

Image B. Interpretation from a single volume acquisition suggests long segment disease with probable stricture and localized perforation, all confirmed on subsequent imaging.

11. Volume imaging of the intestine

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Mohamed Kichouh, sonographer
St. Luc University Hospital, Université Catholique de Louvain, UCL, Brussels, Belgium

Key reasons to consider 2D plus volume imaging approach

Despite the improvement of CT and MRI, sonography is still considered as useful in patients having, or suspected of having, acute intestinal disorders, acute appendicitis, diverticulitis, and inflammatory bowel diseases (IBD). Since at least one year ago, we routinely use volumetric imaging, combined with conventional approach, in patients with bowel inflammation. Detection of gut wall thickening, mural vascularization, abscesses, and fistula are better estimated with this combined approach.

How we do the exam

1. Perform the gut investigation as usual, initially without volume acquisition, with the C5-1, C5-2 or a linear transducer.
2. When a gut wall change or increased echogenicity of the peridigestive fatty tissue appears during the sweeps, do at least two perpendicular volume acquisitions centered on the considered target area with the V6-2 transducer.
3. Check the touchscreen of the iU22 to be sure that all the area to investigate is included in the volume set.
4. Analyze these volume sets with QLAB software during the reporting time, when the patient has already left the practice room.

Clinical impact of new volume imaging approach

- The most relevant contribution of adding volume imaging for scanning in intestinal diseases is the availability of enough images, allowing an optimal comparison and follow-up of patients with complicated forms of IBD (due to abscesses and fistula), in combination with a reduced duration of the examination.
- Volume acquisitions are helpful for a better localization of perigut changes, particularly the fistular tracts and abscesses closely located to bowel segments.
- The availability of volume sets in a storage system allows a better comparison between sequential examinations in order to assess the effect of the therapy.

Case Study 1

A middle age male is admitted for acute left iliac fossa pain. A conventional sonogram is required for the diagnosis work-up. This case is helpful for the demonstration of the diagnostic findings for acute left side diverticulitis and the correlation with CT images.

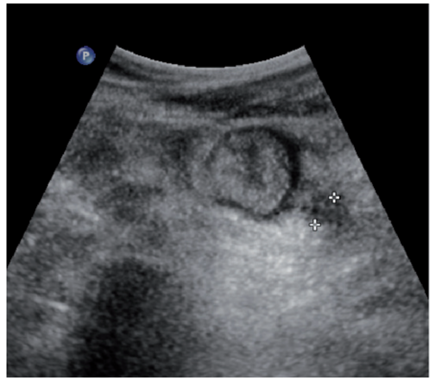


Image A. Ultrasound is showing colic wall thickening, suspicion of inflamed diverticulum and increased echogenicity of the pericolic fat tissue. Volume acquisitions were done for an optimal view of this suspected acute left side diverticulitis.

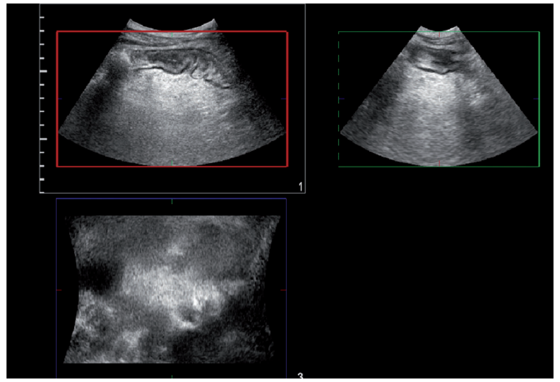


Image B. Acquisition of two volume sets, one in the axis of the inflamed colon and one perpendicular to its long axis.

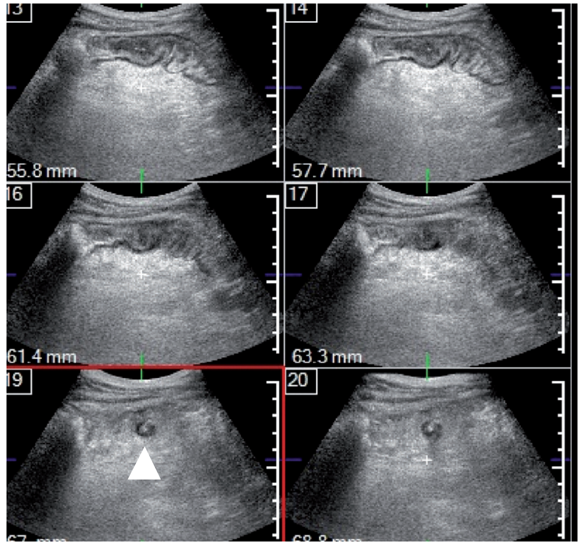


Image C. On the iSlice view, the length of the colic wall thickening is well seen (arrows) as well as the inflamed diverticulum (arrowheads).

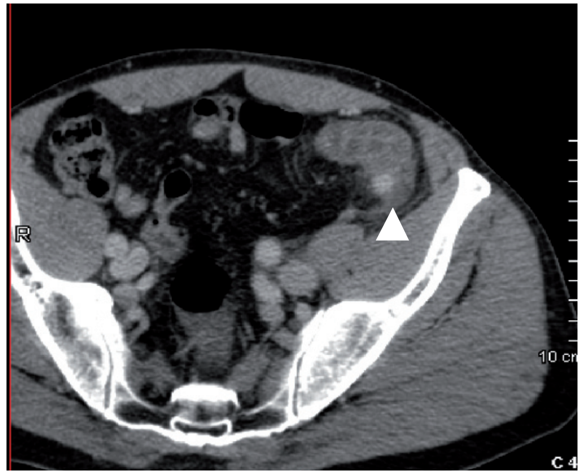


Image D. CT slice at the level of the inflamed diverticulum.

11. Volume imaging of the intestine

Case Study 2

This case is illustrative of the contribution of volume ultrasound for an easier vision of complications in inflammatory bowel disease. This ultrasound was requested for a young female with known Crohn disease and a high degree of clinical suspicion for recurrent complication (abscess and/or fistula).

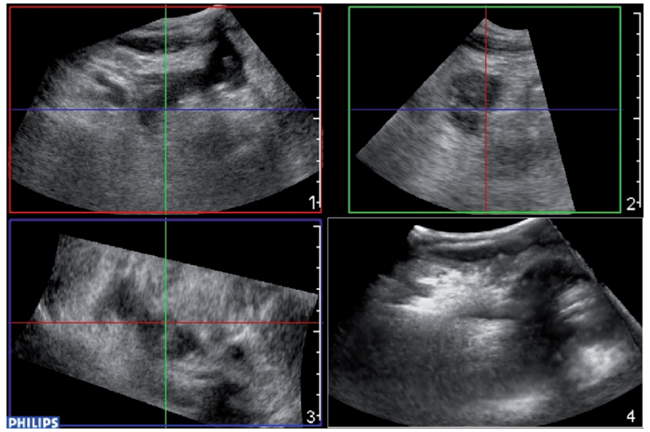


Image A. Initial screen view at the time of acquisition of the volume set.

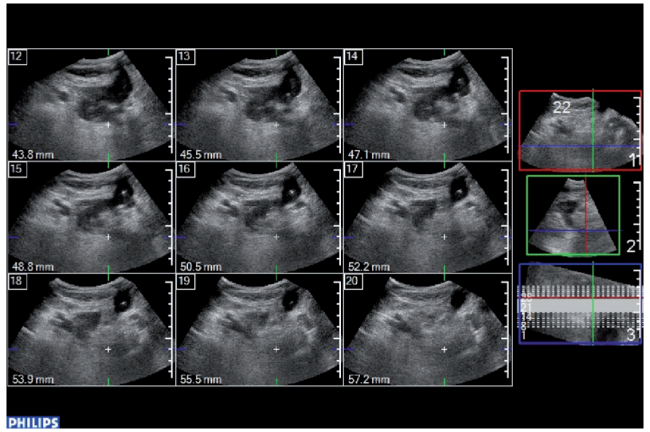


Image B. iSlice screen subdivision at the level of the higher degree of intestinal inflammation.

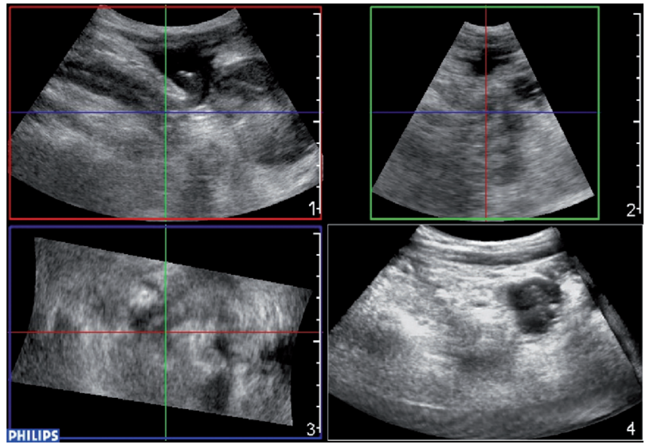


Image C. Reconstructed image obtained after rotating the volume.

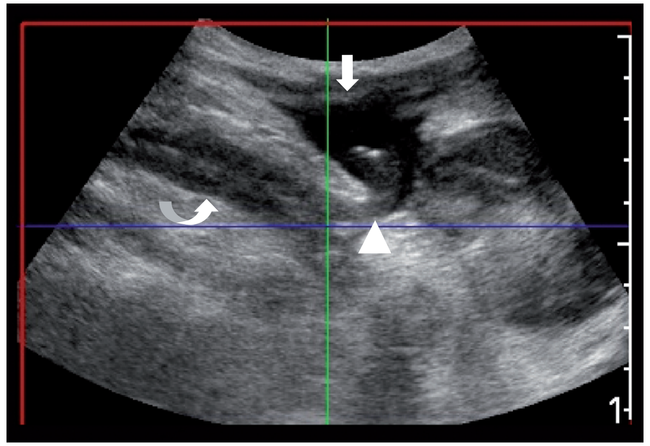


Image D. Closer view of a reconstruction showing a gas containing mesenteric abscess (arrow) connected to the distal ileum (curved arrow) with a fistula (arrowhead).

Case Study 3

A young patient with suspicion of reactivation of Crohn disease. The contribution of volume approach was for a better depiction of the relations between the different segments of the affected ileum, the caecum and the appendix. (The involvement of the appendix was depicted by using iSlice process and reformatted images.)

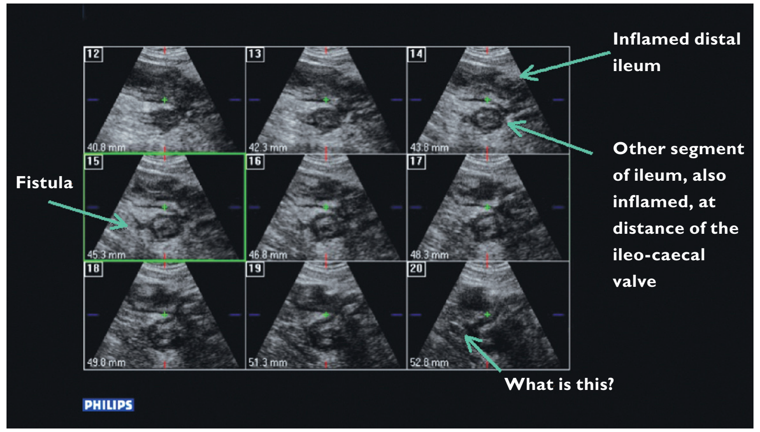


Image A. iSlice screen view at the time of acquisition of the volume set showing the different segments of the inflamed ileum and the fistula.

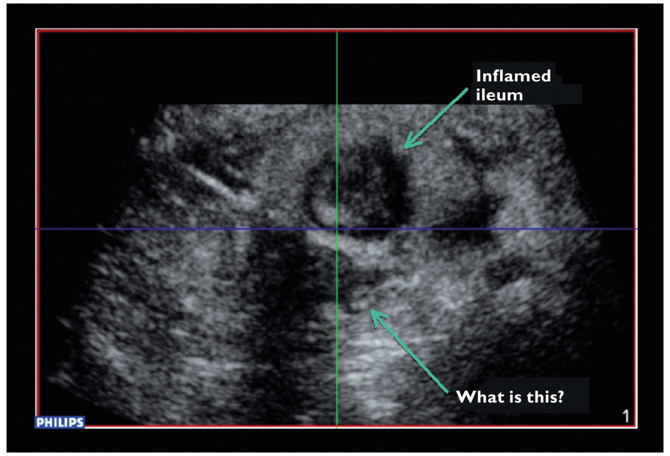


Image B. Reconstructed image obtained after rotating the volume showing the more inflamed ileum and an intestinal segment coming from the caecum.

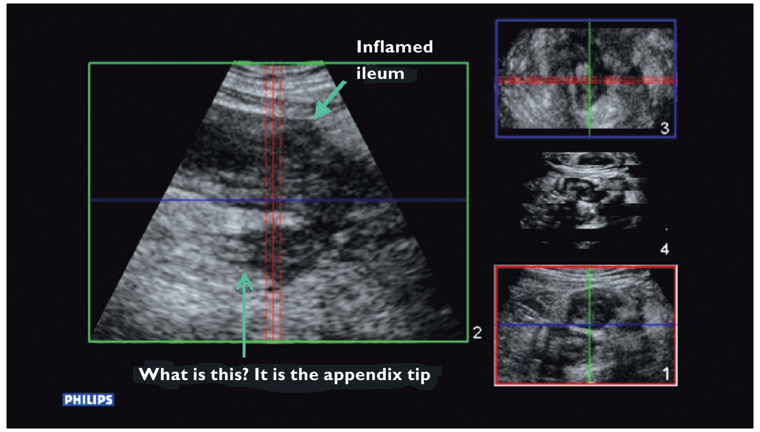


Image C. Additional reconstructed image at the same place after rotating the volume is helpful for the identification of this intestinal segment coming from the caecum: this is the appendix.

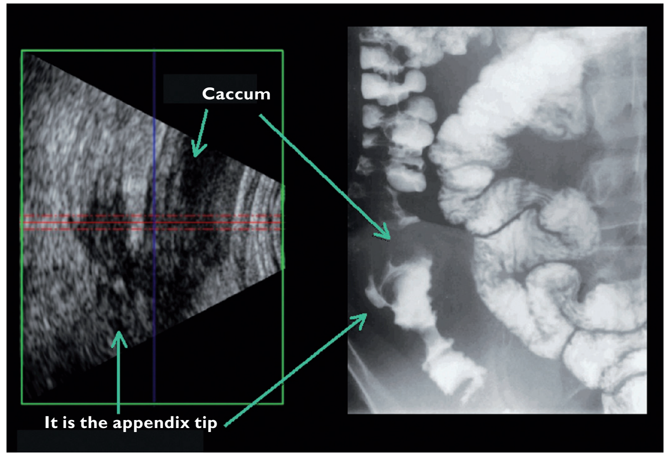
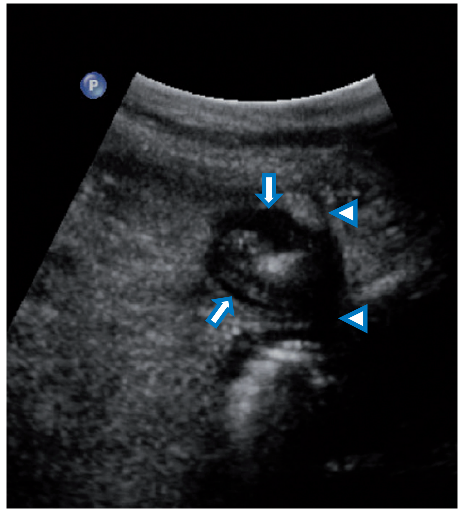


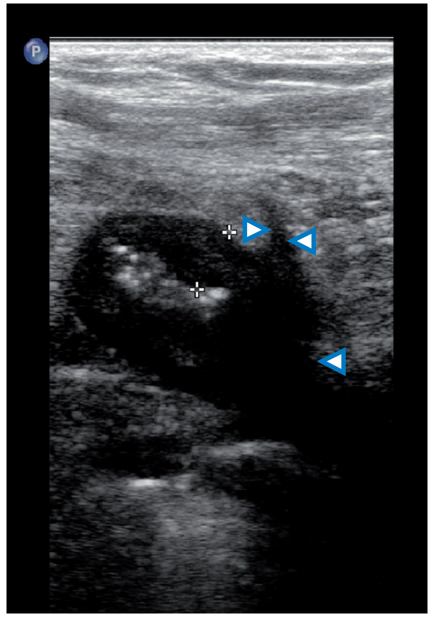
Image D. Correlation between a MPR view of the caecum, the appendix and its connection to the distal ileum.

11. Volume imaging of the intestine

Case Study 4

A young female referred for an ultrasound for suspicion of reactivation of known Crohn disease. Using the volume approach, fistula and abscesses were easier to see.





Images A and B. Conventional ultrasound is showing ileal wall thickening (arrows) and suspicion of fistula (arrowheads) into the inflamed mesenteric folds.

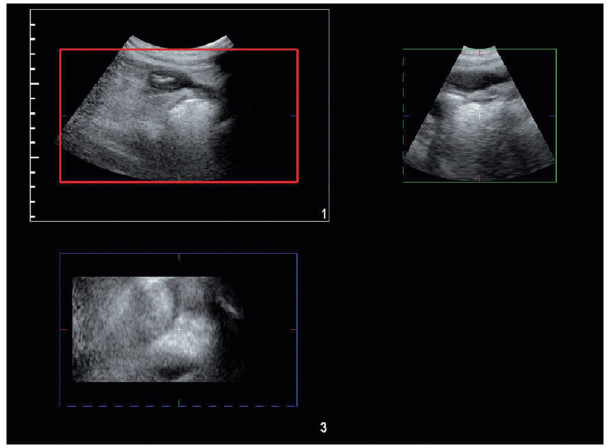


Image C. Global view of the volume set centered just in front of the site of the more pronounced peridigestive changes

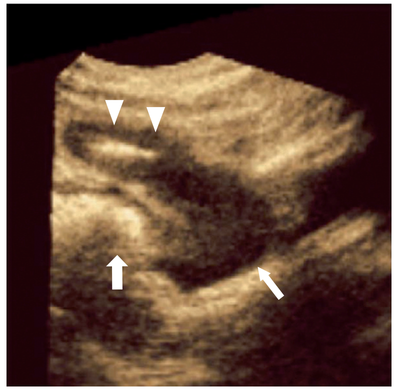


Image D. Ileal wall thickening (arrowheads) with extradigestive, mesenteric hypoechoic process (fistula, thin arrow) connected to another segment of the bowel (large arrow).

12. Volume imaging of the pancreas

Stephanie R. Wilson, MD
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Key reasons to consider 2D plus volume imaging approach

The pancreas is a narrow, thin organ with one long and two short dimensions. Its shape is ideal for the best volumetric acquisitions. The pancreas has constant vascular landmarks which allow for reproducible and consistent results for the volume acquisition.

The pathologies of the pancreas of interest to cross sectional imagers include only two groups of diseases, tumors and inflammatory processes. A tumor is manifest as a mass in the pancreas. Demonstration of a tumor mass in both the long axis and the cross sectional plane is critical to successful interpretation of the nature of the mass and its relation to the vital vascular structures. Inflammatory processes involving the pancreas cause diffuse pancreatic abnormality and abnormality of the surrounding soft tissues. Their study requires comprehensive evaluation of multiple pancreatic and peripancreatic acquisition slices.

With conventional single-frame image acquisition, images in perpendicular planes are acquired. However, with a real-time multiplanar technique, a mass, and its relationships to vital vascular structures, may possibly be viewed with only a single acquisition.

In cystic pancreatic neoplasms, the relationship of the cystic masses to the pancreatic duct is also critical. The volumetric technique may, in a good examination, show the entire duct and its relationship to the cystic mass.

How we do the exam

1. A prescan is performed to identify the pancreas and determine how it is best shown on the sonogram. The prescan assesses whether the patient should lie quietly supine or whether a variety of breathing maneuvers should be employed to optimize the assessment. While searching for the pancreas, we have found that imaging in the saggittal plane, centered on the confluence of the superior mesenteric vein and the splenic vein behind the pancreatic neck, is optimal. From this vantage, the transducer can be angled to the right to show the pancreatic head ventral to the inferior vena cava and then to the left to show the pancreatic tail ventral to the splenic vein and artery as it runs to the region of the hilus of the spleen.
2. Once this pancreatic anatomy is determined, rotation of the transducer to the axial plane will require only slight correction to show the pancreas in its long axis in its entirety, generally by angling the transducer slightly cephalad on the left and slightly caudad on the right.
3. Once attained, the ideal plane for the acquisition should be in the long axis of the gland with the center point set on the spleen vein as it runs from the portal venous confluence to the splenic hilum. The cephalad limit should include the celiac axis and the caudal limits should include the most inferior aspect of the pancreatic head and the duodenal sweep.

In summary, the prescan determines:

- Choice of transducer frequency – generally, standard for abdomen
- Choice of transducer design – curved
- Choice of optimal plane for acquisition – axial, in the long axis of the pancreas as determined by the course of the splenic vein
- Choice of optimal acquisition technique – generally, mechanical
- Choice of optimal phase of respiration – highly variable, ranging from full inspiration, full expiration, quiet breathing and use of breathing maneuvers

12. Volume imaging of the pancreas

Clinical impact of new volume imaging approach

Pancreatic assessment with volumetric acquisition is susceptible to the same challenges that influence the success of routine sonography of this organ. Therefore, even with meticulous technique and maneuvers, there will be a small, but definite, failure rate. Obesity is not the only factor which hampers success. Rather, the relationship and the appearance of the overlying transverse colon seemingly exerts the largest influence on success. Nonetheless, many patients will have excellent volumetric results showing the entire pancreas in a single acquisition.

- A successful acquisition shows the pancreas tissue, the vital regional vascular structures, and the peripancreatic soft tissues.
- Demonstration of a pancreatic mass will show its location, effect on the pancreatic duct and its relationship to vessels.
- A good study is of enormous contribution to diagnosis of pancreatic pathology and, in the case of neoplastic disease, to determine operability.
- Most often, a single acquisition may show the entire gland in a patient with a good acoustic window (Image A).

A mass in the region of the pancreas can be confirmed to be pancreatic or not. The precise location of the mass, as well as its relationship to the vital vascular structures in and around the pancreas, is generally shown. Additional intrapancreatic pathology and peripancreatic pathology will also frequently be included in a good acquisition. Therefore, as with all successful 3D acquisitions, the pancreas may be superbly shown in its entirety.

The pancreas is one of many organs most often evaluated with CT scan. Multiplanar imaging and assessment of AVI files allow for valuable presentation of data with demonstration of relationships and multiple features in a single file. The presentation of data will only improve with removal of the mechanical technique. The benefit afforded by single frame imaging of the pancreas is shared by volumetric acquisition in that pancreatic tumors show striking contrast differential from normal pancreatic tissue. When used in a volume acquisition, this striking ability to show pancreatic tumors allows for improved determination of their resectability (Images B and C). In inflammatory conditions, the extent and amount of peripancreatic change is also optimally assessed with volumetric techniques.

In our own study at the University of Calgary of volumetric imaging in 200 consecutive patients, the pancreas was satisfactorily imaged with volumetric acquisition.

Case Study 1

A normal pancreas is shown in a nine-on-one stacked format in the acquisition axial plane. The center image is the starting point for the acquisition, and shows the splenic vein and the portal venous confluence. A large portion of the pancreas parenchyma shows on this image. The pancreatic head images are shown (top left and top middle). The cephalad border of the pancreas, the celiac axis image, is shown (bottom middle). The three images on the right include the top, axial, and middle long axis, showing the celiac axis. The bottom right image shows the location of the stacked images as represented on the coronal plane.

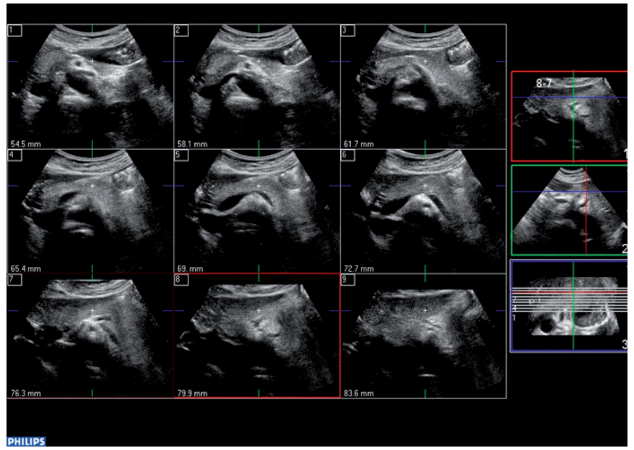

Image A. Normal pancreas in a nine-on-one stacked format in the axial plane.

12. Volume imaging of the pancreas

Case Study 2

Malignant IPMN in an 81-year-old male (Image B, large) shows the acquisition axial plane with the portal venous confluence and an attenuated, but patent, splenic vein. The pancreatic duct is very dilated in the body and tail. A complex cystic and solid mass replaces the pancreatic head. The image (top right) shows the cystic mass in the head in the long axis, and the image (bottom right) shows the dilated pancreatic duct coursing through the pancreatic head. Image C (center image, middle row) shows the splenic vein and the portal venous confluence (left image, middle row). A dilated pancreatic duct is shown in the body and tail. The head is replaced with a complex cystic and solid mass. The bottom images and the other two images in the middle row show the cystic dilated side branches of the pancreatic duct.

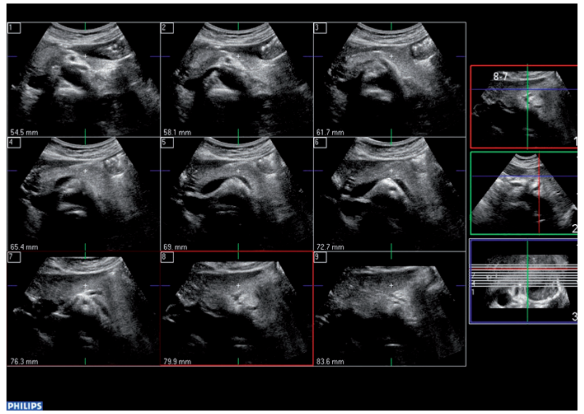

Image A. Normal pancreas in a nine-on-one stacked format in the axial plane.

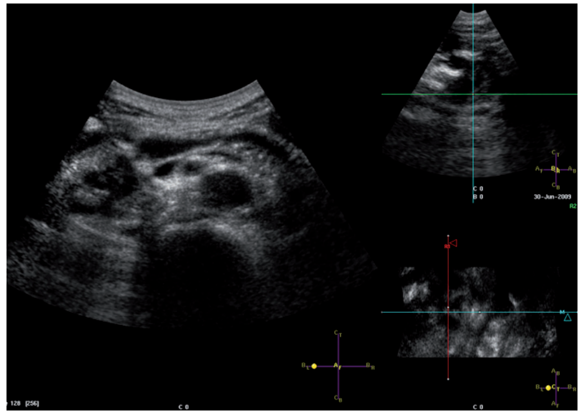

Image B. Malignant IPMN shown with multiplanar reconstruction.

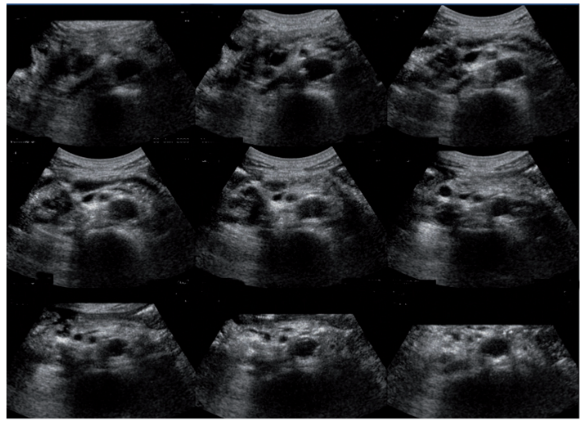

Image C. Malignant IPMN shown in a nine-on-one stacked format in the axial plane.

13. Volume imaging of breast tumors and normal findings

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Key reasons to consider 2D plus volume imaging approach

Better assessment of infiltration in the coronal plane, of the tumor local extension (satellite lesions to a main cancer tumor), and in the C-plane.

This approach offers a new possibility to examine and analyze, by images, the internal structure of the tumors and a better approach to the real size of the lesions.

How we do the exam

Acquisition settings and workflow

1. After localizing the lesion in 2D, proceed to do the volume images.
2. The best 3D image is a result of the best optimized 2D image. Parameters such as the following should be adjusted: gain, depth, focus, frequency, RES/SPD, compression and so on.
3. Tissue aberration correction (TAC) selection always ON.
4. Select maximum angle.
5. Do not use ROI.
6. Select RES option under the 3D menu.
7. Position the transducer to obtain the maximum length of the lesion.
8. The acquisition sweep should extend beyond the borders of the target anatomy to insure that everything is included.
9. No motion during the acquisition is desired.
10. Choose the corresponding orientation labels.
11. Save the 3D data set.

Default data set settings

- 3D vision B
- Volume chroma 3
- Volume Map 2
- Threshold 6%
- Transparency 15%
- Brightness 32%
- Lighting 30%
- Smoothing 0%
- Sono CT and XRes on

Clinical impact of new volume imaging approach

Clinical impact for radiologists

- New and excellent images in the C-plane and better assessment of the behavior of the infiltration in the surroundings to the cancer tumor.
- Better assessment of lesion size and extension.
- Helps increase tumor diagnosis.
- The possibility of seeing the internal structure and an increase in the diagnosis confidence for the benign lesions.

Clinical impact for surgeons

- Better assessment of real lesion size.
- Helps increase confidence in tumor diagnosis.

Clinical impact for oncologists (in big tumors or local advanced disease)

- Better assessment of the tumor's volume which is important to evaluate the response to neoadjuvant therapy.
- Assessment of the internal structure (necrosis) which might help to evaluate the response to neoadjuvant therapy.

13. Volume imaging of breast tumors and normal findings

Case Study 1

A 67-year-old female patient with a 19 mm BI-RADS 5 lesion at one o'clock in the left breast by mammography. Same finding with 2D ultrasound. The 3D volume image (review) shows a satellite lesion not detected with 2D ultrasound or mammography. This is a good example in which the review of the 3D images gives more information about the size and extension of the malignant process, improving the outcomes of the surgery. The pathology specimen showed a 25 mm invasive ductal carcinoma Elston-Ellis grade 2, SN (sentinel node) negative.

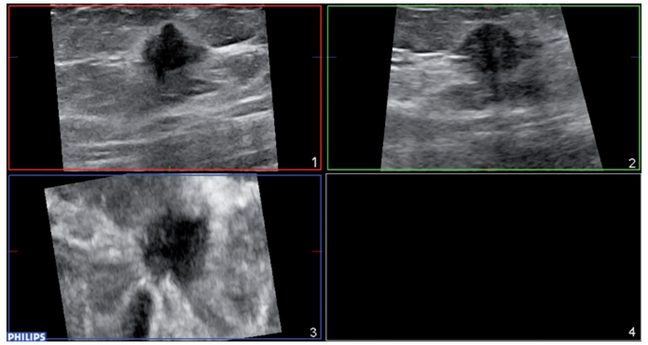

Image A. The 19 mm invasive ductal cancer in its three planes. Note the infiltration visible in the C-plane.

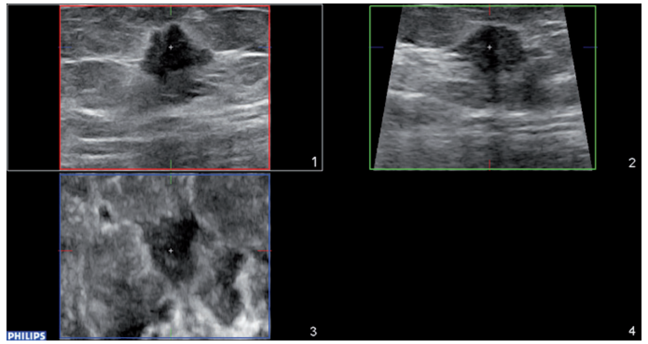

Image B. During the review process in 3D, a satellite lesion close to the main tumor shows up, not detected in the 2D scanning. Now the 19 mm solitary tumor is a 24 mm multifocal process.

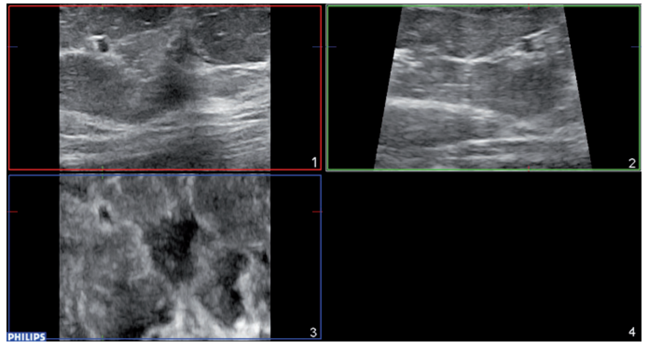

Image C. Detail close-up picture of the satellite lesion in 3D.

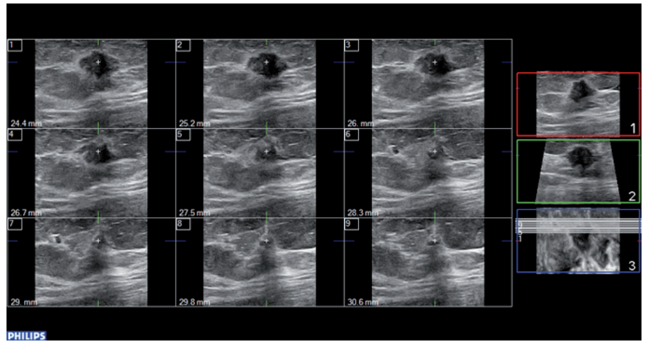

Image D. iSlice view showing the main tumor from frames 1-9. The satellite lesion shows up just in frames 5-7.

14. Volume imaging of the breast

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Key reasons to consider 2D plus volume imaging approach

The addition of volume imaging to traditional 2D ultrasound has proven itself to be of great value in breast imaging. Not only does it add a new plane of ultrasound imaging, the coronal plane, but that plane appears to be a site of preferential growth of some breast malignancies. Standard 2D imaging relies upon sagittal and transverse scan planes. The addition of reconstructed 3D images allows detailed coronal imaging. Tumor growth in the coronal plane appears to represent growth in the pathway of least resistance.

University of Kansas Hospital does a large volume of neoadjuvant chemotherapy for breast cancer. The addition of 3D imaging defines true tumoral geometry with measurements often greater than seen on standard 2D imaging. These measurements, obtained in the coronal plane, typically are greater than traditional imaging. This allows more patients to be offered this excellent therapeutic option based on coronal measurements. Moreover, volume imaging may offer precise volume calculations, allowing early detection of a pending successful neoadjuvant response based on volume decreases as a first sign of a successful neoadjuvant effort.

Some lesions thought to represent satellites may be seen to be contiguous on volumetric imaging. This information may eliminate additional biopsies to define lesions thought to be discontinuous with the primary tumor.

Another merit of C-plane imaging is more thorough representation of the total geometry of any mass. It is rare but possible for a sonographer to misrepresent a complex mass with ultrasound scan planes through rounded, non-representative segments of lesions.

Axillary lymph node imaging is also facilitated by 3D imaging. Eccentric early malignant changes are better shown on 3D review. Scan plane imaging errors, possibly missing small cortical malignancies in a lymph node, now are more easily avoided.

Diagnostic breast ultrasound is often asked to define benign lesions, such as a fibroadenoma, based on two or fewer gentle macrolobulations. With 3D volume imaging we can now truly define the entire surface of the mass in question. This may offer better definition of posterior surfaces.

Acoustic shadowing seen with one third of breast cancers often prevents definition of posterior tissues. 3D imaging reconstructs posterior tissues more clearly, allowing for better measurements and mass characterization.

Rapid accrual of data sets with 3D imaging allows more efficient use of sonographer and physician time with review of 3D images after the patient has left the department.

14. Volume imaging of the breast

How we do the exam

All patients with malignancies greater than 2 cm are considered candidates for neoadjuvant chemotherapy. The sonographer deploys 3D imaging on all these patients, preferably prior to needle biopsy. This typically avoids intra/peritumeral hematomas increasing the calculated volume. The undisturbed tumoral volumes are comparable to volumes derived from MRI however they are based on changes in acoustic parameters not on changes resulting from altered contrast kinetics. This volume may be more accurate, particularly in patients receiving drugs altering capillary permeability (VEGF) and thus diminishing enhancement of the tumor during MRI.

The evaluation of benign masses typically involves acquisition of data sets to be reviewed later. In the evaluation of indeterminate masses, the availability of these 3D images shows signs of being quite useful.

The sonographer determines the long axis of the mass in question. During the five second acquisition time, a steady hand and motionless silent patient are useful. If the lesion is felt to be clearly benign, a review of the data set is now performed. Both malignancies and potentially benign lesions are reviewed from our PACS workstation by both the sonographer and breast physician.

The patients understand the process easily and seem to enjoy the novel images and rapidity of the data acquisition.

Clinical impact of new volume imaging approach

A review of 50 typical cases demonstrated the following:

- 3D imaging provided additional diagnostic information of value in 48% of cases
- Diagnostic confidence increased in 10% of cases
- 3D imaging improved the correlation of physical findings with imaging in 38% of cases
- The addition of volume imaging facilitated measurement technique in 46% of cases

Case Study

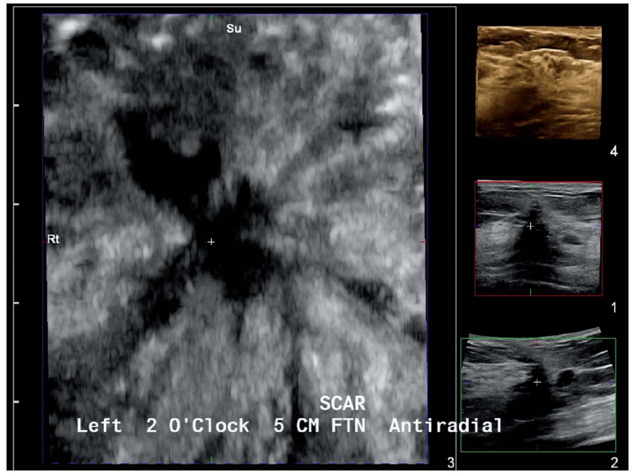

Image A. The addition of 3D imaging allows better characterization of peritumoral spiculation. This is seen far better in the coronal plane. It appears that the coronal plane is a path of least resistance for tumor growth.

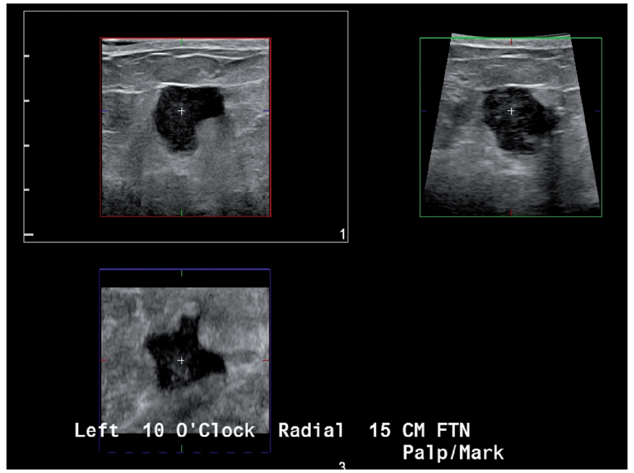

Image B. Mass characteristics, such as microlobulations and angular margins, are seen much better on C-plane imaging.

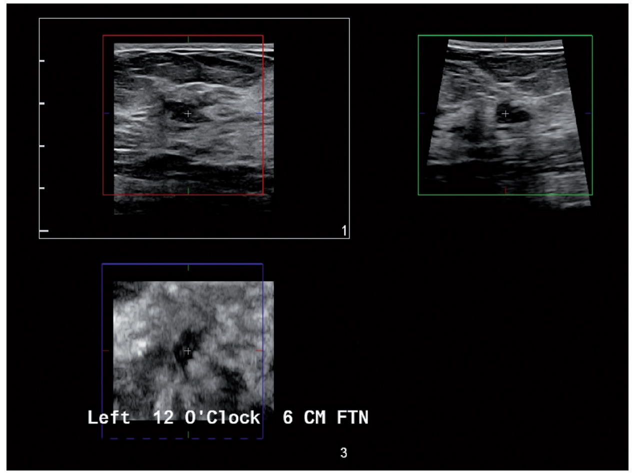

Image C. Anticipated routes of tumor growth, such as intraductal growth, are certainly better seen in these images. Note the linear growth projection seen in C-plane imaging.

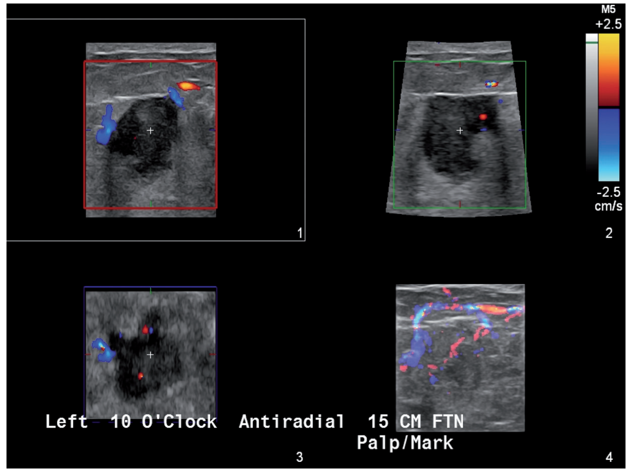

Image D. Macrolobulations, characteristic of benign breast changes, may be difficult to see in standard imaging planes. In this study, this benign mass shows two gentle macrolobulations not appreciated in standard imaging projections. The addition of color Doppler imaging is also useful, particularly for biopsy planning.

15. Volume imaging in gynecologics

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Key reason to consider 2D plus volume imaging approach

The main reason is the fact that the operator is able to obtain a continuous vision of all planes.

This approach is helpful in assessing uterine malformations and the relationship between lesions and adjacent organs, as well as the thickness of cleavage plans in order to plan a surgical strategy.
It is also helpful in the detection of vessels, and the understanding of their relationship with lesions and malformations.

How we do the exam

1. When the scan is performed by an expert sonologist, the 3D acquisition is directed to obtain three planes in order to reach a differential diagnosis. In these cases, the 3D imaging is an integration of the conventional 2D scan and must be directed towards a specific diagnostic question.
2. When the 3D acquisition is performed by an operator who is quite inexperienced in vaginal ultrasound, volume imaging allows a post-processing evaluation performed later by an expert sonologist.
3. Volume imaging allows retrieving diagnostic information that could have been ignored by the inexperienced operator. This is even more important when the scan is performed by an obstetrician, a radiographer or a nurse.

The field of view of the volumetric scan could not contain the entire pelvis. Therefore, we suggest performing:

- A scan that includes the uterus and the right ovarius
- A scan that includes the uterus and the left ovarius
- A scan that includes the uterus and the bladder
- A scan that includes the uterus, the rectum and the Douglas space

Clinical impact of new volume imaging approach

The volume imaging seems to have its best expression in the detection, evaluation, and description of uterine malformations.

In addition, some further features should be considered, such as:

- The possibility of a second look in consensus with the physician who is in charge of the patient. This may allow the integration of the examination with other findings that might not have been considered during the scan.
- The possibility of a second look in consensus with the surgeon who is in charge of the patient. A conjoined evaluation may result in an improved assessment in terms of surgical planning (relationship of the lesion or malformation and its relationship with vessels).

Case Study 1

A 24-year-old female with a history of infertility reported recent occurrence of metrorrhagia and repeated vaginal bleeding. A conventional 2D ultrasound scan showed a relevant thickening of the endometrium (Image A). The scan was performed in the ninth day of the menstrual cycle. Then sonohysterography and 3D imaging were performed. These scans showed multiple endometrial polyps that were lying along the whole circumference of the internal uterine cavity (Image B). In this case, 3D imaging was fundamental in the planning of hysteroscopic resection, demonstrating precisely the site, dimension, and features of each lesion.

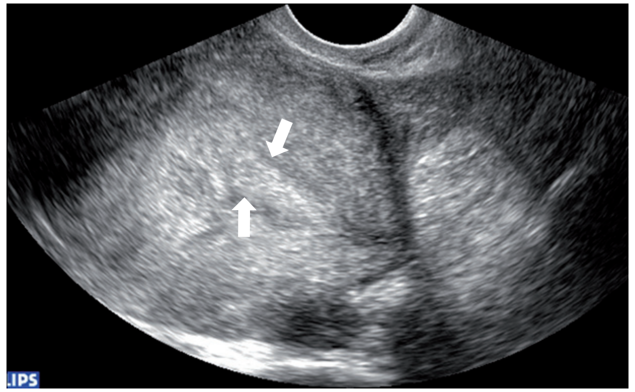


Image A. Thickening of the endometrium (arrows).

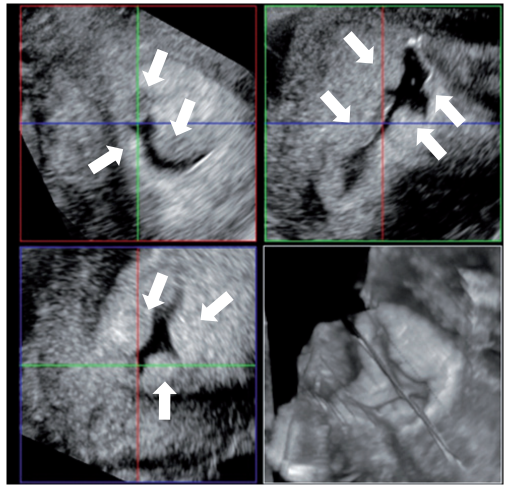


Image B. Multiple polyps in the cavity, in three-plane reconstruction (arrows). Volume reconstruction shows an opened uterine cavity where polyps are clearly demonstrated (arrows).

15. Volume imaging in gynecologics

Case Study 2

A 34-year-old female with a history of infertility and recurrent abortions. Conventional trans-abdominal 2D scan demonstrates a duplication of the uterine body. Both bodies are clearly visible in the axial 3D scan with the bladder in between (Image C). In addition, 3D imaging was the only method to identify the double uterine cervix (Image D). The association with a vaginal septum detected at the gynecological examination allowed us to make a diagnosis of uterus didelphys.

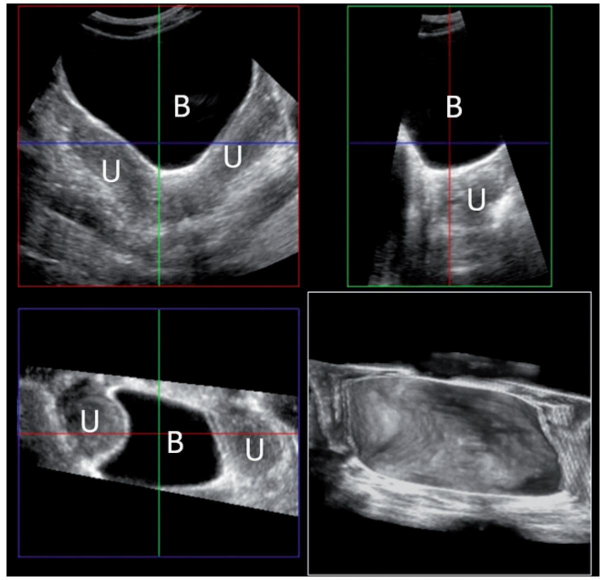


Image C. U = uterine body, B = bladder.

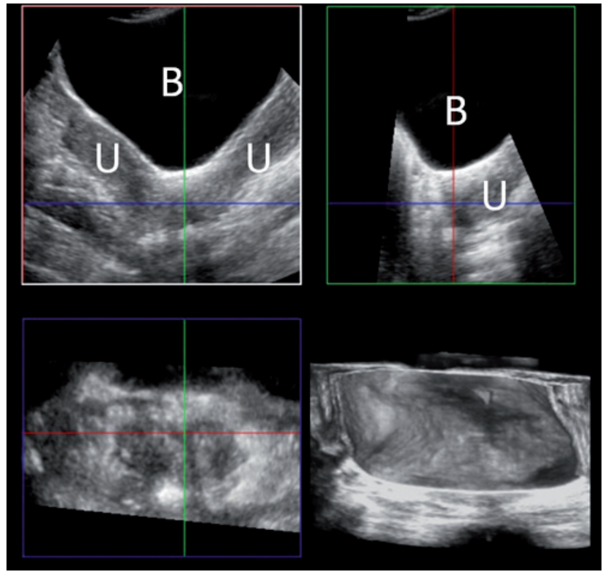


Image D. Cervix duplication.

16. Volume imaging in gynecology

Leonardo Marcal, MD, Randy D. Ernst, MD, Madhavi Patnana, MD, Ott Le, MD, Raghunandran Vikram, MD, Deborah J. Borst, RDMS, RVT, Rhoda M. Reading, RDMS, RVT, and Deepak G. Bedi, MD
The University of Texas M.D. Anderson Cancer Center

Key reasons to consider 2D plus volume imaging approach

3D ultrasound is useful in gynecology for several reasons. First, it provides imaging planes that are simply impossible with 2D ultrasound alone. The coronal view of the uterus, which is critical to correctly diagnose mullerian duct anomalies can only be obtained with volumetric imaging. Second, 3D ultrasound provides depth perception, which cannot be assessed with conventional 2D imaging. Third, it offers advantages when evaluating the anatomic relationship between lesions and adjacent structures and localizing abnormalities in relation to the endometrium and ovaries. In addition, the volume data acquired with 3D ultrasound can be reviewed and manipulated on a dedicated workstation in any desired imaging plane, reducing the need for patient callback. Lastly, the volume data generated by 3D ultrasound can be reliably acquired in less than a minute with a few sweeps of the 3D ultrasound transducer, optimizing patient throughput and satisfaction.

How we do the exam

The 3D ultrasound acquisition is performed by the technologist at the end of the conventional 2D endovaginal ultrasound. Three volumetric acquisition are usually performed; one along the long axis of the uterus in the longitudinal plane, and one acquisition of each ovary in the transverse or longitudinal plane.

1. One volumetric acquisition through the uterus is obtained along the longitudinal plane. Based on the conventional 2D ultrasound images obtained previously, the exact location for optimal placement of the 3D transducer and volumetric sweep are determined. The optimal plane for acquisition is along the midline in the long axis of the uterus in the center of the endometrium.
2. One volumetric acquisition of each ovary is obtained in the longitudinal or transverse plane, whichever plane better delineates the ovaries. Again, the 2D conventional images previously obtained serve to determine which plane will be used for the volumetric acquisition of each ovary.

The volumetric acquisition described above can be easily performed at the end of the conventional 2D endovaginal ultrasound examination in less than a minute. The data is immediately sent to a dedicated 3D workstation where the images can be viewed in any desired clinical plane, to better demonstrate the normal anatomy, pathology, and relationship with adjacent structures that may be of interest. A variety of imaging manipulation tools are readily available in the software, allowing for the "tomographic" display of sequential images in the coronal, sagittal, longitudinal, or transverse planes, or MIP rendered images, similar to what is possible with multislice computed tomography (MSCT) and magnetic resonance imaging (MRI). The imaging post-processing software allows for the manipulation of the slice thickness of each tomographic image, volumetric measurements, Doppler flow measurements, etc., to be obtained utilizing the acquired volumetric data.

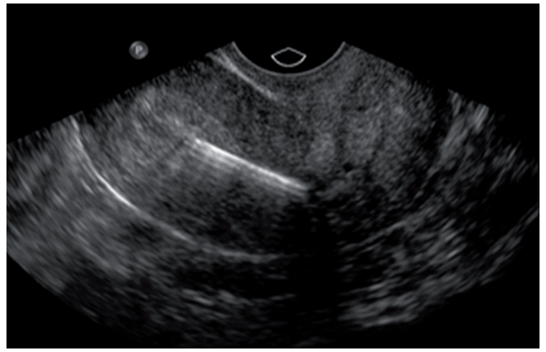
Clinical impact of new volume imaging approach

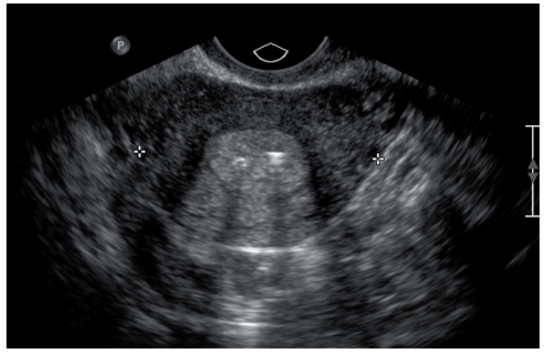
In our study at The University of Texas M.D. Anderson Cancer Center involving 50 consecutive patients, successful volumetric data could be obtained on all patients. The volume data obtained was reviewed at a dedicated workstation by radiologists experienced in gynecologic ultrasound, after review of the conventional 2D images. Our experience showed that the review of the 3D data set on a dedicated workstation increased the diagnostic confidence in the majority of patients, providing additional diagnostic information not available on the conventional 2D images in a significant number of patients. In some patients, the addition of volume imaging changed the initial diagnostic impression, and in many cases, the addition of volume imaging improved the presentation of the findings to the referring physician. Lastly, the addition of volume imaging improved patient throughput in our department, reducing the need for physician rescan after the exam was completed by the technologist. The ability to review the entire dataset of images of the uterus and ovaries, and not only the thin static 2D images of these structures selected for print by technologist, was found to be very useful for most radiologists, even in cases in which no change in diagnosis was made.

16. Volume imaging in gynecology

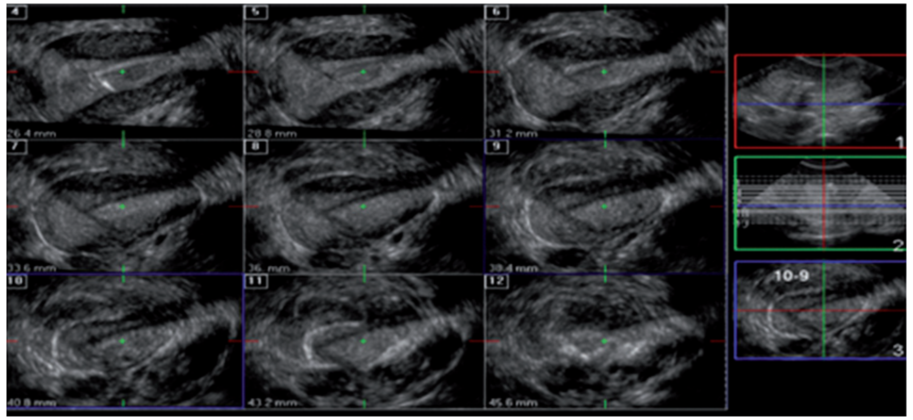
Case Study 1

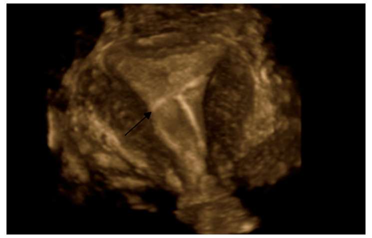
43-year-old female for evaluation of intrauterine device (IUD). The 2D conventional ultrasound images demonstrate an IUD apparently centered within the endometrium (Figures A and B). Volumetric ultrasound examination performed at the same time shows downward displacement of the IUD, which has migrated inferiorly and is now tilted in the body of the uterus (Figures C and D). The ability to obtain a true coronal view of the uterus (impossible with conventional 2D ultrasound alone) and create a 3D rendered image of the entire uterine volume, makes 3D ultrasound ideal for the assessment of the endometrial cavity and volume, being particularly useful in the evaluation of IUD position and migration, which can be quite challenging to assess with conventional 2D images alone.





Figures A and B. Conventional 2D follow-up ultrasound performed shows an IUD within the endometrial cavity. Assessment for IUD migration and position can be challenging with conventional 2D images alone.





Figures C and D. Volumetric 3D ultrasound images performed at the same time show inferior displacement of the IUD, which you can now see is tilted within the endometrial cavity. IUD migration is optimally assessed with 3D ultrasound. The 3D rendered image shows the entire "V"-shaped endometrial cavity to better advantage, making it easier to detect IUD displacement, migration, and potential complications, which can be easily overlooked with thin conventional 2D images alone. In this case, the IUD migration was only diagnosed once the 3D ultrasound images were reviewed.

Case Study 2

46-year-old Chinese female with abdominal pain. Patient reported history of prior IUD placement. The conventional ultrasound images showed an echogenic structure within the endometrium probably representing an IUD. It was only upon review of the 3D volumetric images that the shape and type of IUD could be determined. The 3D rendered images clearly showed a circular IUD, consistent with a "Chinese" ring. This is important clinical information that affects patient care, since the "Chinese" ring requires different management than the standard "T"-shaped IUDs, commonly encountered in clinical practice.

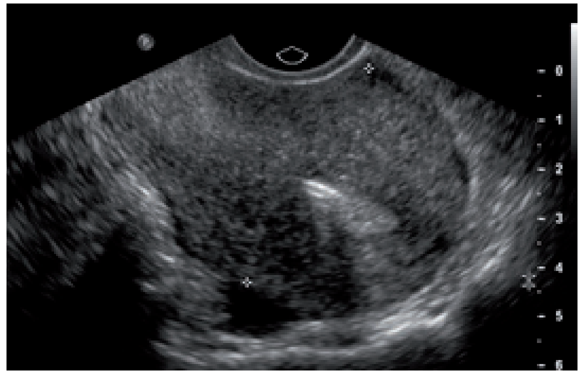


Figure E. Conventional 2D longitudinal ultrasound image shows an echogenic structure within the endometrial cavity, probably representing an IUD. Its shape, type, and exact location cannot be determined with certainty with thin conventional 2D images alone.

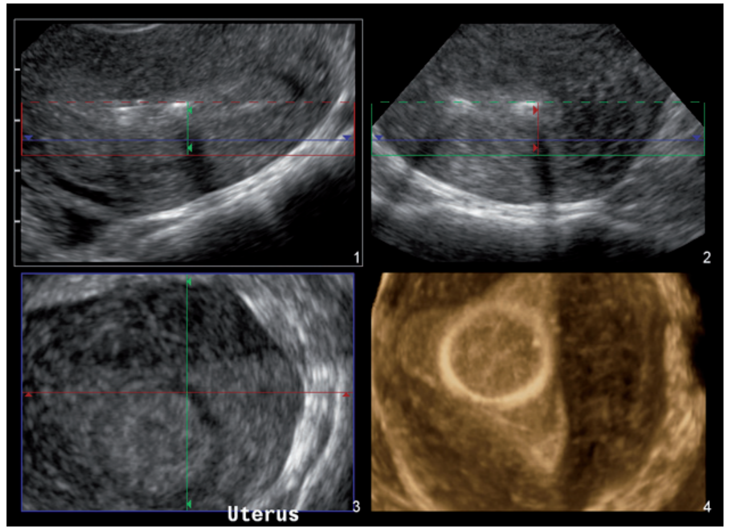


Figure F. 3D ultrasound acquisition of the uterus was performed. Longitudinal (1), transverse (2), and coronal (3) reconstructed views of the uterus were manipulated on the 3D workstation to create a 3D surface rendered image of the entire uterine volume (4).

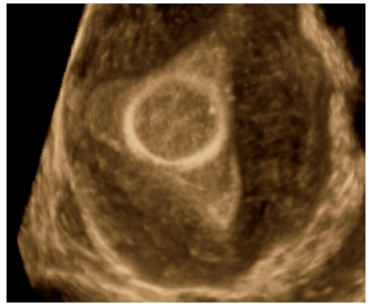


Figure G. The coronal 3D rendered image of the uterus clearly depicts a circular IUD (the "Chinese" ring) centered within the endometrium. This important information (the type, shape, and exact position of the IUD), which certainly impacts patient management, could only be obtained upon review of the 3D volumetric data.

16. Volume imaging in gynecology

Case Study 3

46-year-old Caucasian female with abnormal vaginal bleeding. 2D conventional longitudinal ultrasound image shows a mass centered in the endocervical canal, with a probable stalk leading into the endometrial cavity. Subtle cystic changes are noted within this mass. Multiplanar reconstructed and 3D volume rendered images of the uterus show the endocervical mass to better advantage, facilitating communication of the findings with the referring physicians.

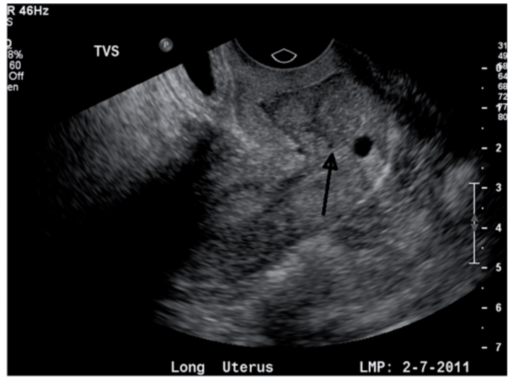


Figure H. 2D longitudinal view of the uterus shows a mass expanding the endocervical canal (arrow) that appears contiguous with the endometrium.

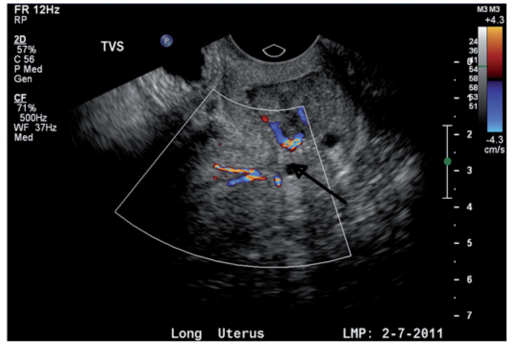


Figure I. Color Doppler longitudinal view of the uterus at the same level suggests the presence of a vascular stalk connecting the endocervical mass to the endometrium.

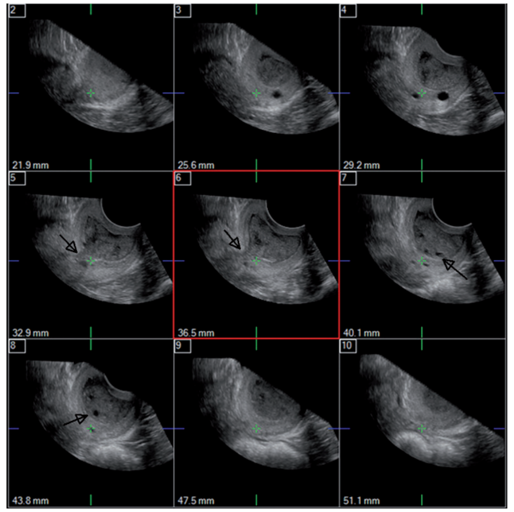


Figure J. Multiple contiguous tomographic longitudinal slices show the endocervical mass to better advantage. The internal cystic changes (arrows) and the connecting stalk (arrows) to the endometrium are more clearly depicted on the reconstructed images.

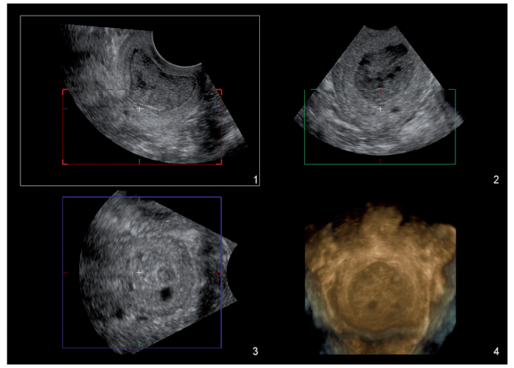


Figure K. Longitudinal (1), transverse (2), and coronal (3) reconstructed images were manipulated on a 3D workstation to create a coronal surface rendered image of the uterus (4), showing the entire volume of the endocervical polyp in a single image. In our experience, the surface rendered images of the uterus are useful to communicate the findings with the referring physicians.

Case Study 4

48-year-old female with abnormal vaginal bleeding. A 2D conventional ultrasound was performed and showed a retroverted uterus. A possible fibroid was suspected in the body of the uterus on the right, although the findings were not definitive to allow a confident diagnostic call, probably due to the retroversion of the uterus. Its relationship with the endometrium could not be determined.

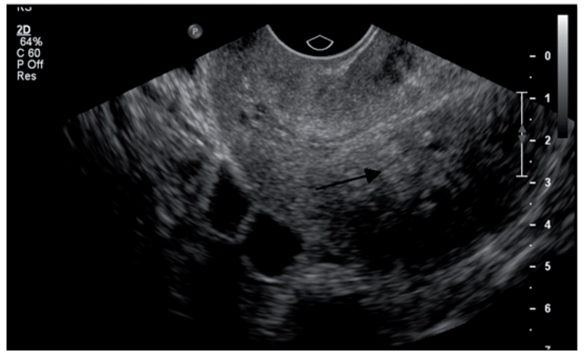


Figure L. Conventional 2D endovaginal longitudinal view shows retroversion of the uterus. An area of heterogenous echotexture with suggestion of internal shadowing was suspected in the body of the uterus on the right, possibly representing a fibroid (arrow).

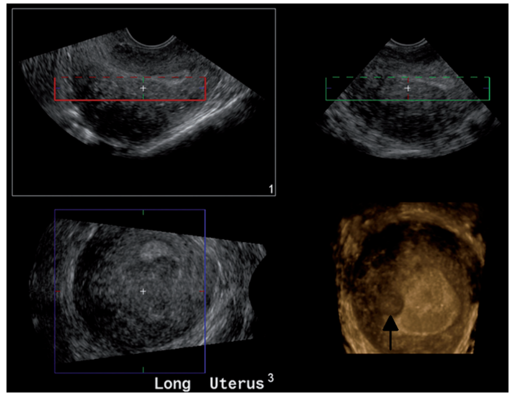


Figure M. Multiplanar longitudinal (1), transverse (2), and coronal (3) reconstructed images of the uterus were manipulated on a 3D workstation to create a 3D surface rendered image of the uterus in the coronal plane (4). A submucosal fibroid is clearly identified in the body of the uterus on the right (arrow). The fibroid size, location, and its relationship with the adjacent endometrium are better demonstrated on the 3D images.

16. Volume imaging in gynecology

Case Study 5

50-year-old female with abnormal vaginal bleeding. A conventional 2D ultrasound was performed and showed an elongated mass in the lower uterine segment and cervical region, probably representing an endocervical polyp.

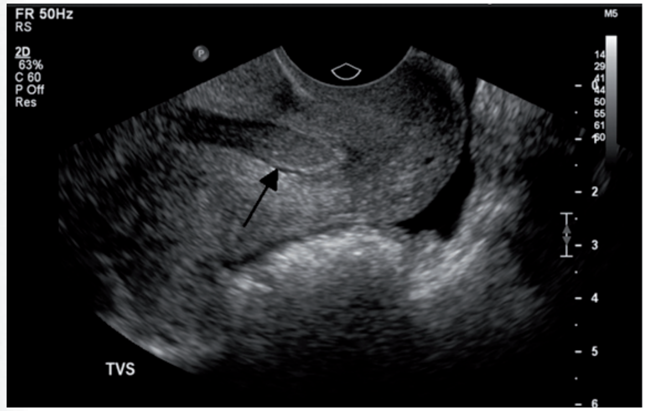


Figure N. Conventional 2D longitudinal view of the cervix and lower uterine mass shows an elongated mass, probably representing a polyp. The true size and extent of the polyp cannot be well demonstrated on a single 2D longitudinal image, and review of the entire dataset of conventional images is necessary to obtain this information.

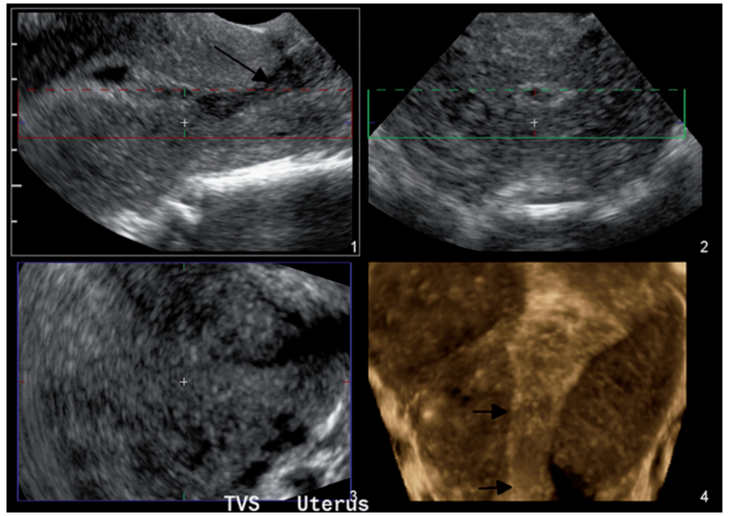


Figure O. Multiplanar reconstructed images (1, 2, and 3) and 3D volume rendered image of the uterus show an elongated mass in the lower uterine segment, extending into the endocervical canal, consistent with a cervical polyp. The ability to manipulate and triangulate the volume dataset in a 3D workstation is helpful to better demonstrate pathology that extends from the endometrial cavity into cervix.

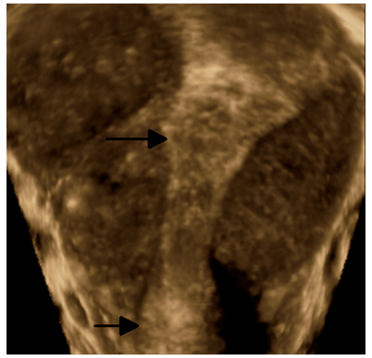


Figure P. Coronal surface rendered display view of the uterus shows the entire endometrial cavity in a single image, with an elongated mass extending from the lower uterine segment into the cervix (arrows), compatible with an endocervical polyp.

17. Volume imaging of the uterus

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Key reasons to consider 2D plus volume imaging approach

The uterus may vary considerably in position. It may be retroverted posteriorly to varying degrees. It may be tilted to the right or left and/or rotated about its long axis.

Fibroids are frequently encountered during transvaginal scanning and their presence tends to lead to obstacles in scanning. Large or multiple fibroids may elongate or displace the uterine cavity. Because fibroids typically attenuate sound, adequate penetration and sufficient imaging may be problematic necessitating a transabdominal approach.

Obese patients or those who have knee or hip problems cannot tolerate being in the lithotomy position. These patients need to be scanned while positioned on their side with their knees brought in toward their chest.

A vaginal transducer has limited mobility within the confines of the vagina. This leads to limited planes of scanning. Angulated uteri present further limitations on the transducer to image perpendicular to the long axis of the uterus resulting in suboptimal endometrial visualization. Incorporating volume imaging into the scanning protocol may overcome these challenges.

Because sonographic images are obtained from a volume of ultrasonographic data rather than from a slice of data, the findings may be less operator dependent. Additional findings can be made after the patient has left the department by "scrolling" through the volume data. There is greater freedom to manipulate or rotate the volume as needed to clarify findings and obtain additional detail after reconstruction.

How we do the exam

1. An initial "survey" scan is done to determine the orientation of the uterus. This will determine optimal placement of the transducer and ensure it is lined up with midline plane of the uterus.
2. We prefer the plane of acquisition to be along the long axis of the uterus. Due to varying uterine positions, this is the most reliable plane to orient the transducer and in our experience is associated with less operator variability.
3. The transducer may have to be rotated to align with the uterus if it is tilted or twisted.
4. Acquisition may be performed in two volumes: one centered on the uterus, the other with the transducer repositioned to optimize imaging of the cervix and lower uterine segment.
5. Drag the MPR crosshair to the tip of the lower pole. Rotate the kidney image around this point by turning the Y-axis control, until the maximum renal length is displayed.
6. Measure the renal length, pole to pole, using conventional calipers.

17. Volume imaging of the uterus

Clinical impact of new volume imaging approach

We performed pelvic sonography in 100 patients with successful uterine volumes obtained in most of the patients. Unsuccessful scans were related to the presence of fibroids or restrictions to performing the scan transvaginally. In a handful of cases, volumes could not be successfully obtained due to patient inability to remain stationary for the examination.

Uterine enlargement due to fibroids frequently requires a transabdominal approach. While volume imaging may not adequately image the entire enlarged uterus, it may provide information that is not readily apparent with 2D as the presence of multiple fibroids tends to distort the uterine cavity and contour. Volume imaging may reveal a submucosal component to fibroids, enough to explain abnormal patient bleeding. While MRI may outperform ultrasound in evaluating the location size and number of fibroids, volume imaging may detect pedunculated fibroids which precludes treatment with uterine artery embolization regardless of number and location of other fibroids present.

Other conditions that affect the myometrium can be clarified by volume imaging:

- The presence of and degree of myometrial invasion in patients with endometrial cancer can be detected and depicted by allowing more planes to be displayed.
- Adenomyosis, in particular the echogenic endometrium extending into myometrium, can be diagnosed with greater confidence.

With respect to the endometrium and endometrial cavity, volume imaging allows for reconstruction of angulated uteri to improve visualization of endometrium. This may prevent overestimation of endometrial thickening when the endometrium is imaged in an oblique plane. IUD malposition can be characterized due to improved visualization of the arms of the device after volume manipulation. This can save the patient from having to undergo hysteroscopic evaluation.

With sonohysterography, volume imaging provides several advantages:

- It shortens the procedure time, therefore decreasing time of patient discomfort.
- It assists with distinguishing polyps from physiologic endometrial thickening.
- More polyps may be detected than with 2D scanning as polyps may overlap each other or be out of view due to their orientation. Treatment strategies can be modified based on this additional information.

In the workup of Mullerian duct anomalies, volume imaging can provide increased accuracy in describing fundal contour and morphology, an important determining factor in triaging these patients for treatment. Coronal images of the uterus can be easily reconstructed providing a better view of the fundus. The volume can be rotated in such a way to ensure accuracy of measurements. Internal cavity morphology can be determined with added sonohysterography.

Case Study 1

39-year-old female with abnormal uterine bleeding. Sonohysterogram demonstrates thickened irregular endometrium. The differential diagnosis in this case includes physiologic endometrial thickening versus polyp. Because of the location of physiologic thickening/orientation of the polyp, the stalk could not be seen in the traditional 2D scanning planes.

Reconstruction confirmed the presence of a polyp which saved the patient a repeat procedure to be performed at the beginning of her cycle when the endometrium is at its thinnest. We were also able to describe the location of the polyp origin, aiding treatment.

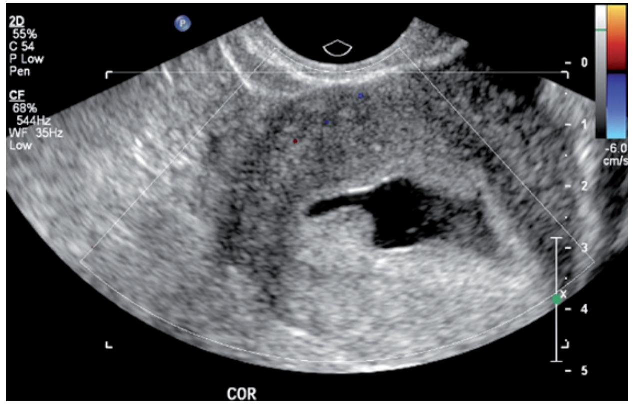


Image A.

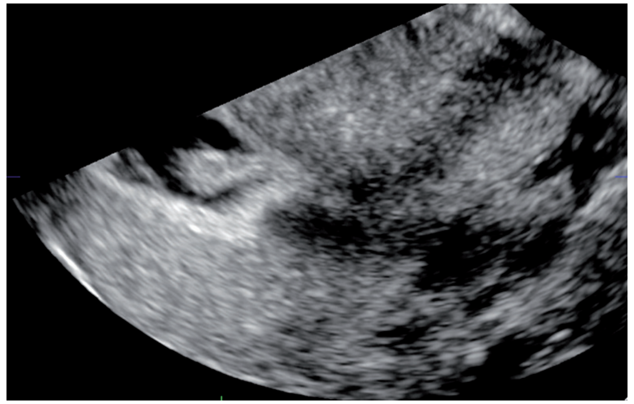


Image B.

17. Volume imaging of the uterus

Case Study 2

39-year-old patient with history of difficulty getting pregnant. She had been told by her doctor that she has a congenital uterine abnormality based on a procedure that was done in his office. She presents to the department for sonohysterography. The initial transvaginal ultrasound was normal.

Once saline was infused, we could see the presence of a linear echogenic structure within the endometrial cavity. Volume reconstruction in the coronal plane clarified that this is not a septum but rather a synechia.

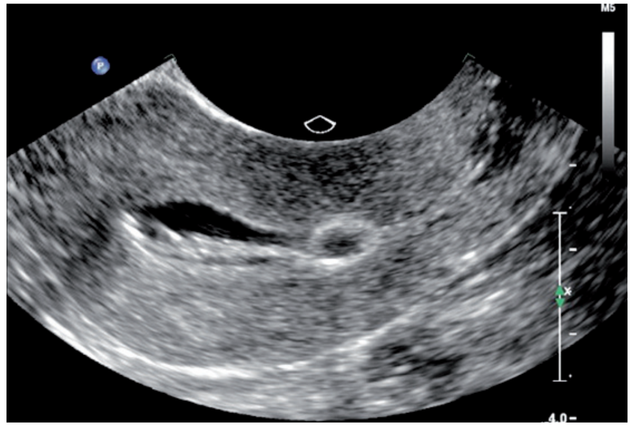


Image C.

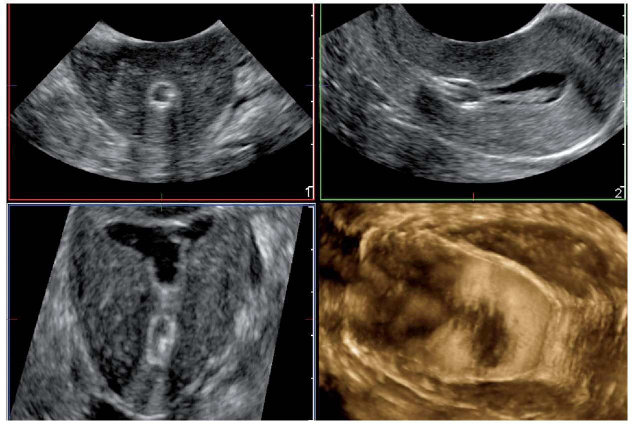


Image D.

Case Study 3

42-year-old female presents for infertility workup. 2D transvaginal scan of the uterus suggests the presence of two endometrial cavities. Coronal reconstruction of volume shows rounded contour of fundus distinguishing septate uterus from bicornuate uterus.

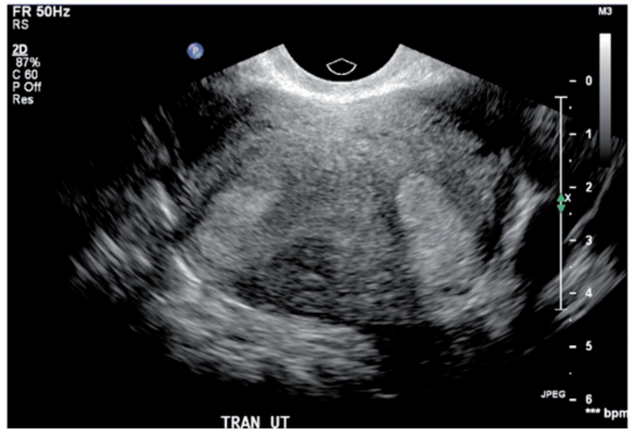


Image E.

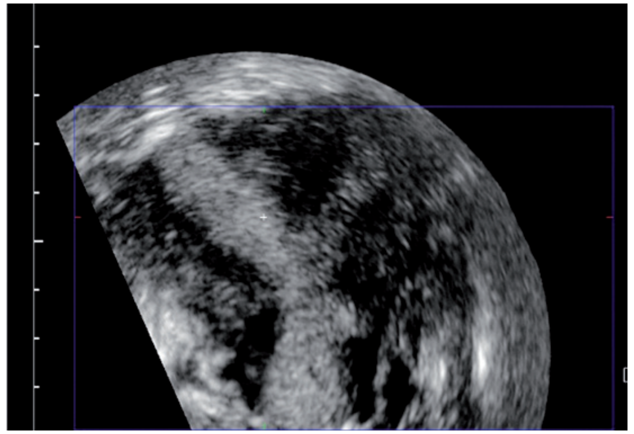


Image F.

18. Volume imaging of a tumor of a renal transplant

Michel Claudon, MD
Centre Hospitalier Universitaire, Nancy, France

Key reason to consider 2D plus volume imaging approach
Capability to conduct a full volumetric examination, including 3D grayscale and 3D color Doppler mode. This type of examination allows the evaluation of small tumors in any plane, including those which could not be displayed by 2D modes.

How we do the exam

1. After the 2D evaluation, use the VL13-5 MHz transducer, as the lesion is superficial.
2. Based on a coronal view, cover the entire area with a 40 degree sector angle. Multidirectional reformation shows the appearance of the tumor, and its relationship with the kidney capsule and parenchyma.
3. For 3D color Doppler imaging, use low PRFs and decrease the gain to minimize motion artifacts and concentrate on main vessels. Superimposing Doppler signals in a volume nicely demonstrates vascularity.
4. In QLAB, work within a thick slice to display anomalies and obtain images which can be compared with CT reformatted images.

Clinical impact of new volume imaging approach
Higher spatial resolution and better information on vascularity than provided by 2D ultrasound, CT, and MRI.

Case Study

A small round shaped tubulo-papillar carcinoma was discovered in upper pole of the renal transplant on MRI follow-up in a 30-year-old male. Subsequent evaluation was made on ultrasound and CT.

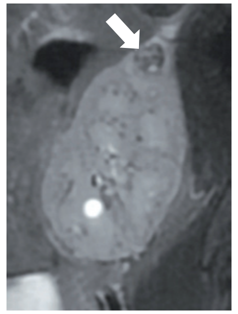


Image A. T2-weighted MRI image demonstrates a 1.2 cm tumor in the upper pole of the allograft (arrow).

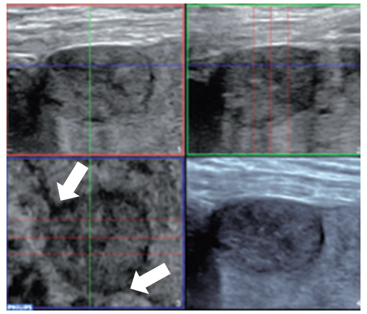


Image B. Multiplanar display of the tumor and its relationship with adjacent capsule and parenchyma, especially in the sagittal plane (arrows).

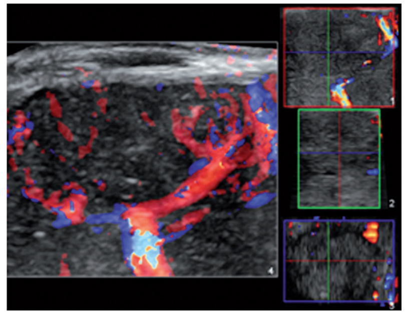


Image C. Thick slice obtained from a 3D color Doppler volumetric acquisition shows feeding vessels and spare intratumoral vascularity.

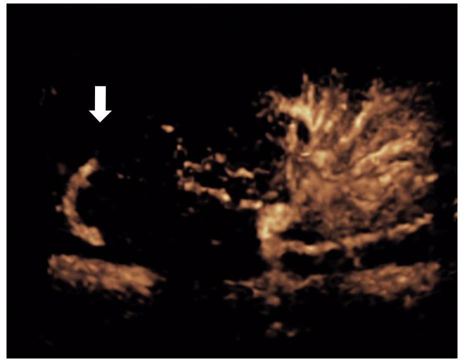


Image D. Based on a 3D acquisition, calculation of infracted and vascularized parenchymal volumes can be easily performed. Values are respectively 109 ml and 81 ml.

19. Volume imaging of the testicle

Michel Claudon, MD
Centre Hospitalier Universitaire, Nancy, France

Key reason to consider 2D plus volume imaging approach

Difficulties in evaluation of the extension of a varicocele upon 2D acquisition.

How we do the exam

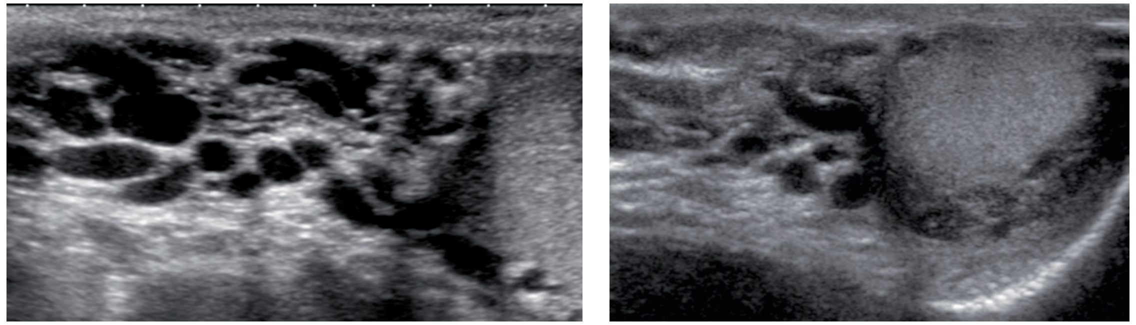
1. After the 2D evaluation, use the VL13-5 MHz transducer as the varicocele and testicle are superficial.
2. Based on a sagittal view, cover the entire area with a 40 degree sector angle.
3. Multidirectional reformation shows the appearance of the varicocele in a spectacular way, and its relationship with the upper pole of the testicle.

Clinical impact of new volume imaging approach

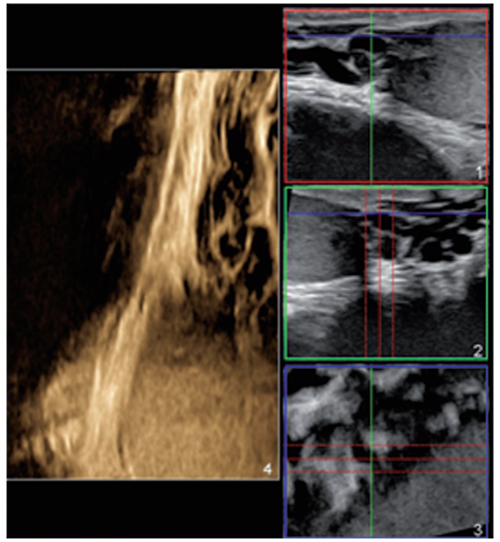
Better display of the persistence of the varicocele despite an embolization of the internal spermatic vein.

Case Study

A 15-year-old male being evaluated for recurrent left varicocele after embolization of the internal spermatic vein. Evaluation of the varicocele.



Images A and B. 2D ultrasound confirms the persistence of the varicocele which surrounds the upper pole of the left testicle.



Images C. 3D volumetric acquisition nicely demonstrates the varicose venous network covering the testicle.

20. Volume imaging of nutcracker syndrome

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Key reason to consider a 2D plus volume imaging approach

Insufficient evaluation of the entrapment of the renal vein by 2D imaging.

How we do the exam

1. After the 2D evaluation, use the V6-2 MHz transducer.
2. Based on a transverse approach, select a sector angle of 30 degrees, which allows the coverage of the epigastric area.
3. For 3D grayscale imaging, use harmonic imaging, optimize depth, gain and focus, and make the acquisition during a breath hold.
4. In QLAB, work within a thick slice to display anomalies and obtain images.

Clinical impact of new volume imaging approach

Better anatomic description of the venous entrapment (diameter, length).

Case Study

A 15-year-old male being evaluated for recurrent left varicocele after surgical ligature. Evaluation of the left renal vein for a potential compression between the aorta and superior mesenteric artery (suspicion of nutcracker syndrome).

Image A. Left renal phlebography shows moderate renal varices (arrows) and compression of the main renal vein at the level of the aorta (arrow).

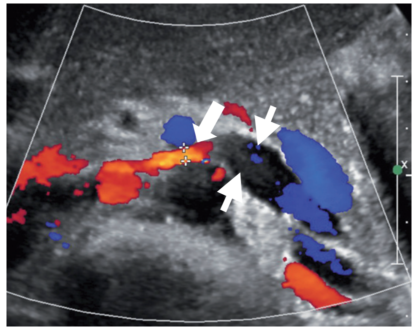

Image B. Transverse color Doppler view shows a dilated renal vein and high flow at the level of the segment between the aorta and the superior mesenteric artery (arrow).

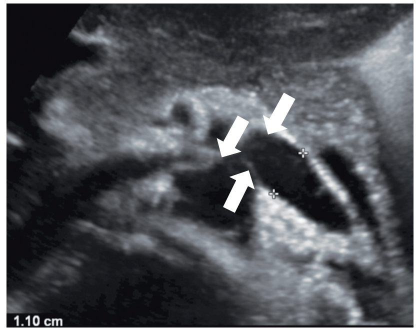

Image C. 2D grayscale imaging hardly shows the entrapment of the renal vein between the aorta and SMA.

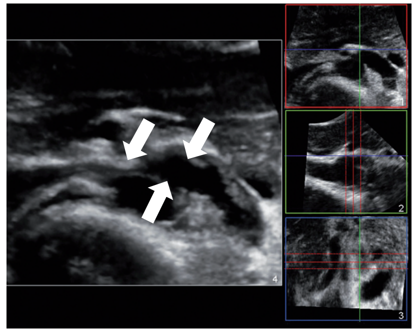

Image D. 3D grayscale imaging nicely shows the entrapment of the renal vein between the aorta and SMA, with a 0.5 mm diameter and 5 mm length.

21. Volume imaging of the bladder

Michel Claudon, MD
Centre Hospitalier Universitaire, Nancy, France

Key reasons to consider 2D plus volume imaging approach

The volumetric complement is very useful to display the size and the implementation of the recurrent polyp developed at the bladder neck, and considered potential risk for outlet obstruction.

How we do the exam

1. After the 2D evaluation, use the V6-2 MHz transducer.
2. Based on a transverse axis, select the adequate sector angle to cover the bladder neck area (40 degrees).
3. Use harmonic imaging, optimize depth, gain and focus.
4. In the post-treatment phase, use QLAB and work with the thick slice mode (24 mm) with the slice centered on the bladder neck.

Clinical impact of new volume imaging approach

Allows a cystoscopy-like display of the lesion, and makes non-invasive follow-up easy.

Case Study

A two-year-old female, having a Beckwith-Wiedemann disease diagnosed since birth, presenting with a bladder polyp, initially resected by cystoscopy. Follow-up by ultrasound shows recurrence of the polyp three months later.

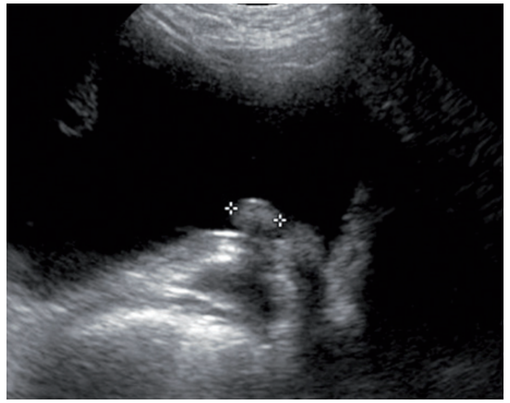

Image A. Transverse 2D view shows the recurrent small polyp close to the bladder neck (diameter 7 mm). The precise shape and relationship with the bladder neck cannot be easily assessed.

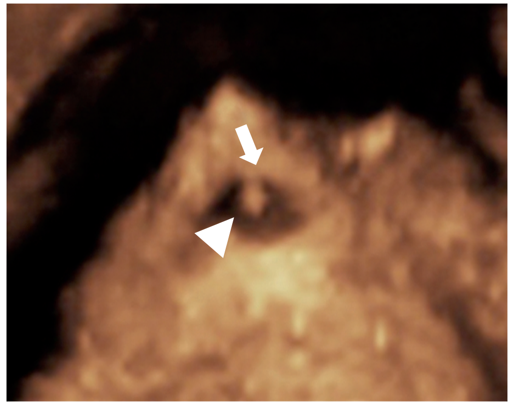

Image B. 3D imaging allows for cystoscopy-like images. Demonstration of the polyp basis (arrow) and of development just above the bladder neck (arrowhead) can be better assessed on 3D data than on 2D images.

22. Volume imaging of the bladder

Michel Claudon, MD
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Key reason to consider 2D plus volume imaging approach

Better demonstration to the referring surgeon of the anatomical findings.

How we do the exam

1. After the 2D evaluation, use the V6-2 MHz transducer.
2. Based on a transverse axis, select the adequate sector angle to cover the trigone area (40 degrees).
3. Select harmonic imaging, optimize depth, gain and focus.
4. In QLAB, use the multiplanar reconstruction and determine which plane would be the most useful to display abnormalities (here, the coronal view).
5. Work within a thick slice to produce the cystoscopic view.

Clinical impact of new volume imaging approach

- Easy confirmation of the widely opened ureteral orifice.
- The inadequate location of the per-endoscopic injection of material, to prevent from reflux into the upper urinary tract.

Case Study

A 10-year-old male, presenting with grade 4 right vesico-renal reflux in a megaureter, causing recurrent urinary tract infection (UTI). The urologist injected, by endoscopic approach, a gel of dextranomer microspheres around the ureter orifice to prevent urine from flowing back up. An ultrasound is performed because of a new episode of UTI.

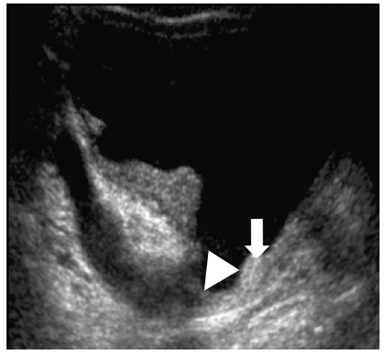

Image A. 2D ultrasound shows an opened ureteral orifice within the bladder (arrowhead) and deflux amount distant from the orifice (arrow).

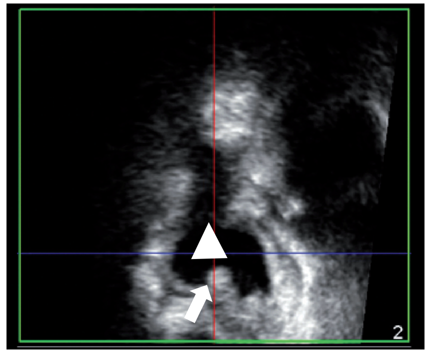

Image B. 3D acquisition allows the reconstruction of a coronal view which could not be obtained directly, confirming the widely opened lower ureter (arrowhead).

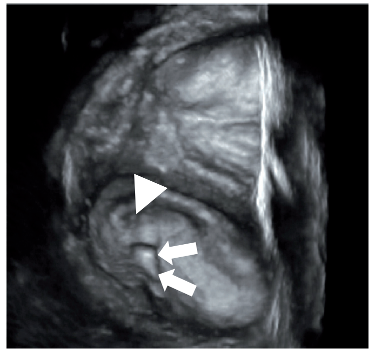

Image C. A 3D cystoscopy-like view better demonstrates the orifice remaining opened, and the distant, inefficacious, gel ball.

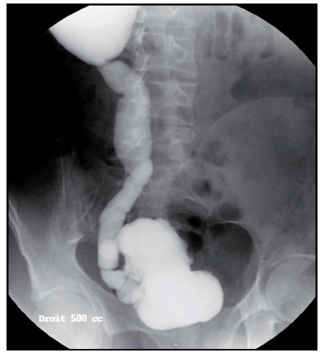

Image D. Radiological voiding cystography confirms the massive reflux in the upper tract through the opened ureteral orifice.

23. Volume imaging of a traumatic kidney

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Key reasons to consider 2D plus volume imaging approach

Better display of vascular traumatic lesions and calculation of the volume of parenchyma remaining perfused.

How we do the exam

1. After the 2D evaluation, use the V6-2 MHz transducer.
2. Based on a long axis view, select a large sector angle to cover the entire renal area (60 degrees).
3. For 3D grayscale imaging, use harmonic imaging, optimize depth, gain and focus.
4. For 3D color Doppler imaging, use rather high PRFs and decrease the gain to minimize motion artifacts and concentrate on main vessels.

Clinical impact of new volume imaging approach

Better follow-up of the patient, based on ultrasound, instead of repeated CT scans.

Case Study

A 14-year-old female, who fell from a bridge. Pain in the left lumbar fossa, hematuria. In this context, a CT scan was performed first, showing a fracture of the spleen, a traumatic dissection of the main left renal artery and a patent inferior polar artery feeding the left kidney lower pole.

3D ultrasound was performed a few days after to follow the evolution of lesions, confirming the absence of vascularity within the middle and upper pole, and a patent inferior artery with normally vascularized lower pole.

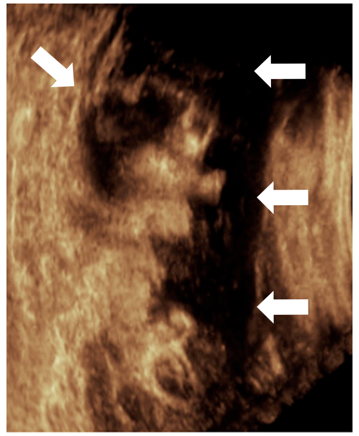

Image A. 3D grayscale ultrasound image shows hypoechoic middle and upper pole of the left kidney (arrows).

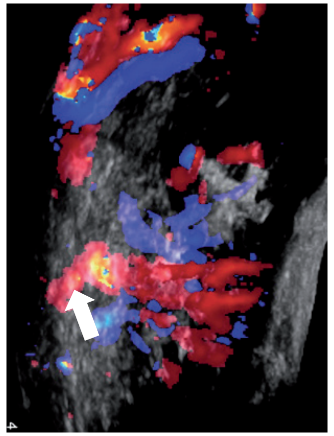

Image B. 3D color Doppler nicely displays the absence of vessels in the middle and upper poles and the patent lower polar artery (arrow).

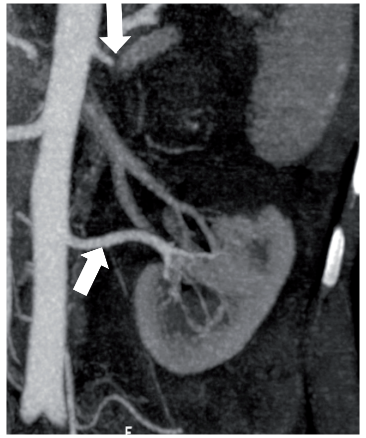

Image C. Coronal CT scan image shows the absence of perfusion of the upper left kidney, and lower pole normally perfused by the polar artery (arrow).

24. Volume imaging of the shoulder (rotator cuff)

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Key reasons to consider 2D plus volume imaging approach

The shoulder is one of the most common fields of application of ultrasound in the musculoskeletal system. In the last years, many changes have occurred that have had a positive impact on the practice of shoulder ultrasound, including improved visualization of shoulder structures, refinement of the criteria for diagnosing rotator cuff tears, and standardization of the examination technique.

Conventional 2D ultrasound requires systematic scanning of each of the four rotator cuff tendons (that is, subscapularis, supraspinatus, infraspinatus, and teres minor) and the long head of the biceps tendon according to long-axis and short-axis planes. Some inter-observer variability is related to this process.

In specific working settings (such as, ultrasound exams performed by medical sonographers and remote teleradiology context), volume ultrasound can contribute to overcoming operator dependence and to improving the accuracy of identification of rotator cuff tears. In addition, it can play a role in better delineating of normal and pathologic findings in patients with rotator cuff disease.

Volume ultrasound enables capture of the whole rotator cuff in three datasets: anterior (for the subscapularis), cranial (for the supraspinatus), and posterior (for the infraspinatus and teres minor). The posterior dataset can give simultaneous depiction of the posterior recess of the glenohumeral joint. Superficial to the rotator cuff, the subacromial-subdeltoid bursa can be evaluated in each sweep by considering its anterior, superior, and posterior aspects respectively.

The biceps tendon is excluded from 3D volume analysis due to both its excessive length relative to the file of view of the acquisition volume and curved course at the intraarticular level, when the tendon reflects over the convexity of the humeral head, leading to variable degrees of anisotropy during the automated sweep. Thus, after 3D volume acquisition, the exam needs further 2D ultrasound complement to assess the biceps tendon. AC joint evaluation can also be accomplished using conventional 2D technique at the end of the study.

The three datasets are reviewed in several planes, including the C-plane, which is parallel to the tendon width and cannot be obtained with conventional 2D ultrasound.

How we do the exam

1. Using the VL13-5 transducer, locate the rotator cuff tendons as for conventional 2D scanning.
2. Optimize the gray-scale settings using the highest resolution possible.
3. The volume ultrasound acquisition consists of three sweeps over the rotator cuff tendons obtained with the patient seated on a revolving stool and the examiner located in front. The shoulder should be positioned as follows:
   a. Anterior sweep – The patient's arm is externally rotated to move the subscapularis tendon anteriorly. (This maneuver helps to reposition it from underneath the coracoid.) In this position, align the A-plane (the basic 2D scan plane) with the midline of the long axis of the subscapularis.
   b. Cranial sweep – The patient's arm is extended posteriorly and the palmar side of the hand is placed on the superior aspect of the iliac wing with the elbow flexed, directed posteriorly and towards midline. (This maneuver helps to reposition the supraspinatus tendon from under the acromion.) In this position, align the A-plane with the midline of the long axis of the supraspinatus.
   c. Posterior sweep – The patient's hand is placed on the ipsilateral thigh, palm up. In this position, align the A-plane with the midline of the long axis of the infraspinatus.
4. Before starting the 3D sweep, tilt the transducer over the rotator cuff tendons to minimize anisotropy over the area of interest. Use large amounts of gel to ensure good acoustic coupling in the peripheral part of the transducer.
5. After selecting large sweep angles, start 3D sweep. During each sweep determine if the structure of interest (either the subscapularis, or the supraspinaus, or the infraspinatus-teres minor complex) has been included in the dataset. If not, repeat the sweep.
6. Press Save 3D Volume to store.
7. Review data using MPR and postprocessing algorithms provided by the QLAB 3DQ GI software.

Clinical impact of new volume imaging approach

- With volume ultrasound, MPR reconstruction and, particularly, the C-plane can enable identification of new details of tendon morphology not provided by conventional 2D ultrasound (Image A).
- In full-thickness tears of the rotator cuff, volume ultrasound can contribute to better delineation the tear width and the amount of tendon retraction (Image B).
- In rheumatologic disorders, volume ultrasound may help to quantify the amount of effusion or synovitis distending the glenohumeral joint recesses and the SASD bursa. Volume assessment of the synovial space may open new perspectives to compare follow-up exams and assess the response to therapy (Image C).
- The stored dataset provides a permanent record of the exam, for second reading, review or audit.

24. Volume imaging of the shoulder (rotator cuff)

Case Study

A 68-year-old male presented with shoulder pain and disability. Conventional 2D ultrasound diagnosed the presence of a full-thickness tear of the supraspinatus tendon. Volume ultrasound confirmed the presence of the tear and allowed effective measurement of its width and retraction.

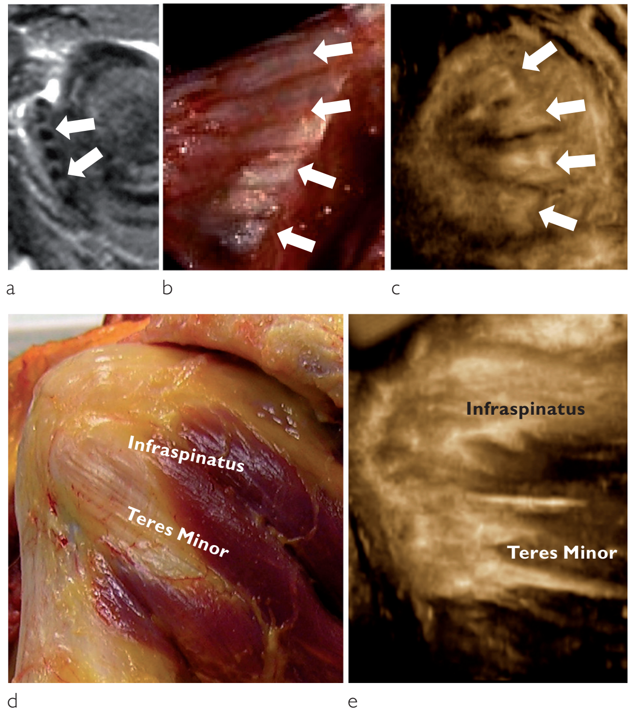
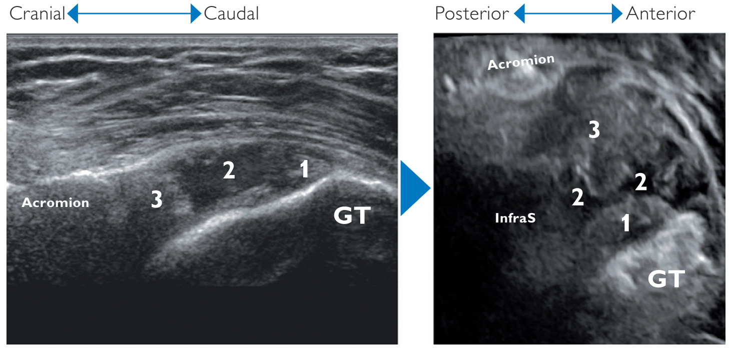
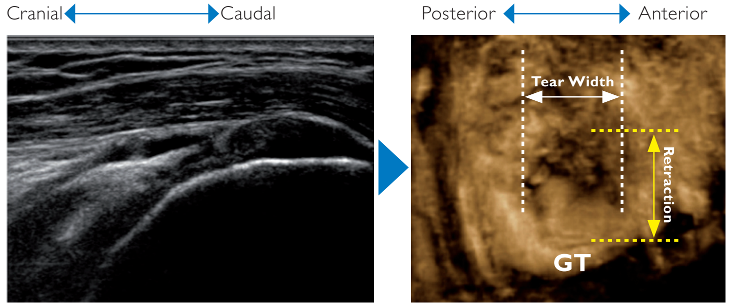


Image A. Normal subscapularis tendon (a, b, c). This tendon has a multipennate structure (arrows) made of multiple bundles of fibers (arrows) converging toward the lesser tuberosity (Lt). This complex arrangement of fibers can be appreciated on GRE T2* MR imaging (a), anatomic specimen (b) and volume US with MPR (c). Normal infraspinatus and teres minor tendons (d, e). Anatomic specimen (d) and volume ultrasound image (e) demonstrate the paired tendons of these two muscles as they converge toward the posterior aspect of the greater tuberosity.



a. Long axis view. b. Width view (C-plane).

Image B. Full-thickness tear of the supraspinatus tendon. Long axis 2D ultrasound (a) and volume ultrasound scan (b) over the ruptured tendon demonstrate some torn fibers (1) inserted into the greater tuberosity (GT), the gap of the tear filled with fluid (2) and the retracted tendon (3). In B, the tear width is better delineated on the C-plane.



a. Long axis view. b. Width view (C-plane).

Image D. (a) Long axis 2D ultrasound and corresponding (b) volume ultrasound image oriented on the C-plane of a small full-thickness tear of the supraspinatus tendon. With appropriate multiplanar reconstruction, volume ultrasound allows adequate delineation of the tear width and the amount of tendon retraction from the greater tuberosity (GT).

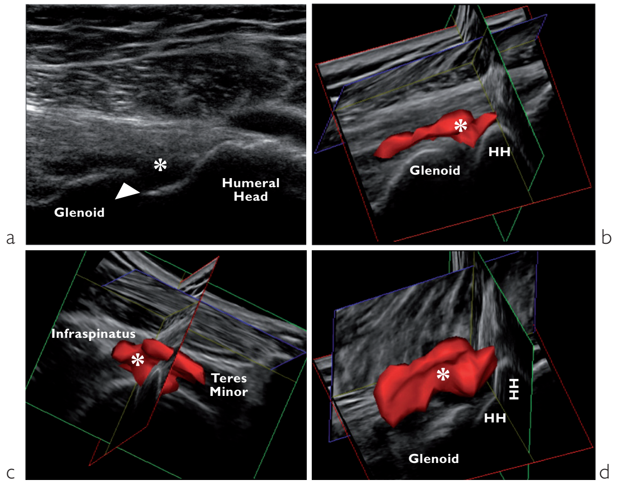


Image C. Volume estimation of the posterior recess of the glenohumeral joint. (a) Posterior transverse 2D ultrasound image reveals anechoic effusion (asterisk) distending the recess and surrounding the posterior labrum (arrow), just deep to the infraspinatus tendon. (b, c, d) After postprocessing, the posterior recess is rendered as a red object and it is shown (asterisk) at different view angles. Quantification of the fluid content was also feasible (not shown). Humeral head (HH).

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