GE Healthcare

High performance 2D imaging

A GE Voluson® technology review

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Abstract

Ultrasound is an intimate imaging modality that provides the clinician and patient with immediate feedback. Two-dimensional (2D) imaging is the standard acquisition mode, and it reliably delivers high-quality images in numerous clinical applications. Today, with advances in technology across all imaging modalities, clinicians are demanding more from their 2D images.

Ultrasonic properties differ greatly between various organs, anatomical features and patients. No single setting or acquisition mode is optimal for every patient or examination. For clinicians to achieve optimal image quality, it is vital that they be able to leverage a number of techniques and select the right tools for each specific case.

GE's Voluson ultrasound systems, recognized by clinicians for its Volume Ultrasound (3D/4D) capabilities, also excels in its 2D imaging. The Voluson system offers a variety of 2D modes to help the clinician see more in every exam. These modes include harmonic imaging (HI); a frequency compounding technique called Focus and Frequency Composite (FFC); second-generation Speckle Reduction Imaging (SRI II); and a spatial compounding technique called CrossXBeamCRI™ (CRI). Each of these features can make a clinically meaningful difference by helping to optimize image quality in specific applications.

Fundamental 2D Image

High resolution is essential to acquiring high-quality ultrasound images. The resolution of an ultrasound system can be described by its axial (along the scan line) and lateral (across the scan line) resolution. High ultrasound frequencies, which provide superior axial and lateral resolution, suffer from increased attenuation when propagating through human tissue. Therefore, the clinician must make a trade-off between high spatial resolution and sensitivity when viewing structures deep in the body.

The frequency range function available on the Voluson enables clinicians to easily switch between three settings: high-resolution/low- penetration, mid-resolution/mid- penetration, or low-resolution/high-penetration. Every Voluson transducer has predetermined settings that are easily controlled with the frequency flip switch on the console, providing optimal acquisition for any clinical scenario.

Harmonic Imaging (HI)

When an ultrasound beam passes through human tissue, it generates signals at higher frequencies, known as harmonics. This phenomenon, the result of a physical effect called non-linear propagation, normally degrades ultrasound image quality. It is possible, however, to take advantage of these higher frequencies by filtering out the original ultrasonic signal and viewing the higher frequencies, which have correspondingly better resolution with fewer artifacts (see Figure 1).

Harmonic imaging has a number of potential clinical benefits, including improved spatial resolution to permit visualization of smaller objects, and improved contrast resolution to improve demonstration of increasingly subtle differences in grayscale. These benefits are most apparent in the mid-field portion of the ultrasound image.

The Voluson has an advanced harmonic imaging mode that uses pulse inversion technologies. This mode is automatically activated by setting the flip switch to "harmonics high" and uses a significantly larger effective bandwidth that simultaneously provides good axial and lateral resolution. The technology enables transmission of two separate single-cycle ultrasound pulses with opposite phase. Upon reception, the Voluson system adds the signals from the two transmissions and cancels the fundamental signal, resulting in high-resolution harmonic signals.

Applications

Obstetrics: Acquiring highly detailed views of organs in early gestational ages, reducing haze, clutter, and artifacts while providing clear distinction between amniotic fluid and tissue structures.

Gynecology: Imaging ovarian cysts and tumors, showing clearer boundaries and better visualization of structures.

Vascular: Scanning the carotid artery, brachialis, femoralis, or vertebralis, yielding improved contrast and axial resolution.

Radiology: Near-field applications such as breast, adult gallbladder, and pediatric abdomen.

Limitations

Because harmonic imaging uses a high receive frequency, the reduced penetration limits the usefulness in deep tissue imaging or for imaging larger patients.

Figure 1
(A): Fundamental imaging (B): Harmonic imaging

Cases

The fetal umbilical cord is displayed with and without pulse inversion. The image acquired using harmonics with pulse inversion displays a cleaner umbilical artery lumen and results in better border definition (see Figure 2).

Harmonics with pulse inversion can be combined with SRI II and CRI as demonstrated by the first-trimester images below. This combination of 2D modes results in clear border definition in the near and far field (see Figure 3).

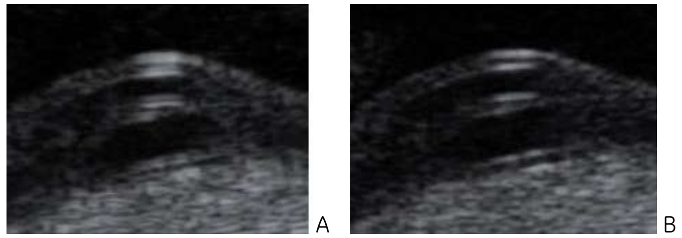

Figure 2
(A): Without pulse inversion (B): With pulse inversion

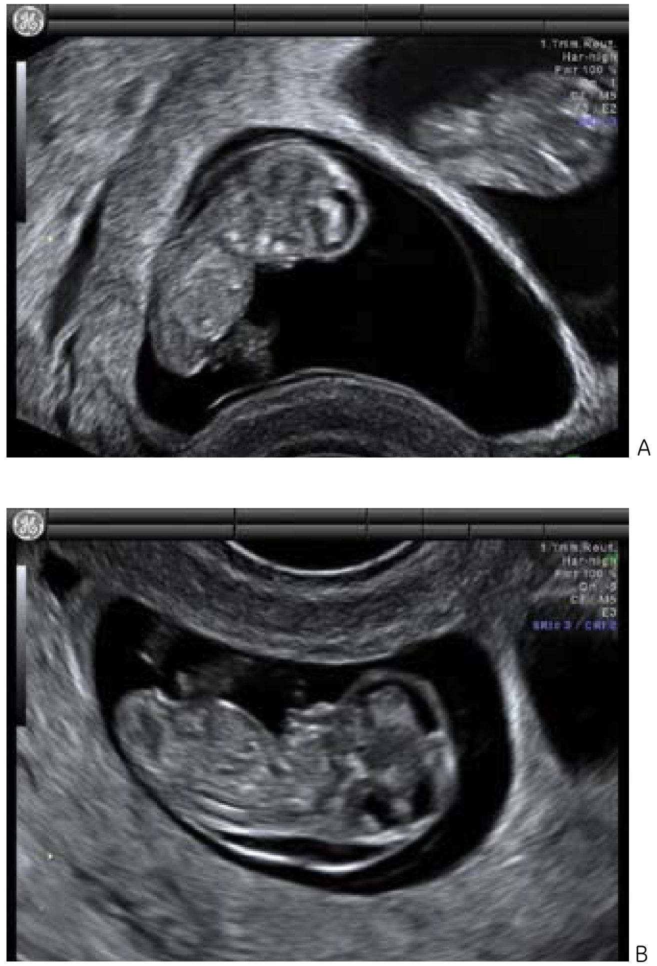

Figure 3
(A): 9-week fetus (B): 10-week fetus

Focus and Frequency Composite (FFC):

While harmonic imaging is not recommended for larger patients, frequency compounding techniques such as FFC on the Voluson system help to meet that clinical challenge. FFC uses two different transmit frequencies and two different focal ranges in the 2D image. For each ultrasound image line, two separate pulses are transmitted: the first with a higher frequency and near field focus, the second with a lower frequency and deeper focus. The resulting image has a wide focal range and considerably improved penetration with reduced speckle and artifacts.

Applications

Obstetrics: Difficult scan conditions and deep penetration, such as third-trimester scans.

Gynecology: Better border definition in deeply located organs.

Limitations

As low frequencies are used for far-field penetration, axial and lateral resolution will be reduced.

Case

A fetal survey is shown in fundamental, harmonics, and FFC (see Figure 4). The image acquired in the FFC mode exhibits better detail at depth as FFC combines the penetration from the low-frequency signal with the near-field resolution from the high-frequency signal.

FFC is available on all Voluson convex transducers.

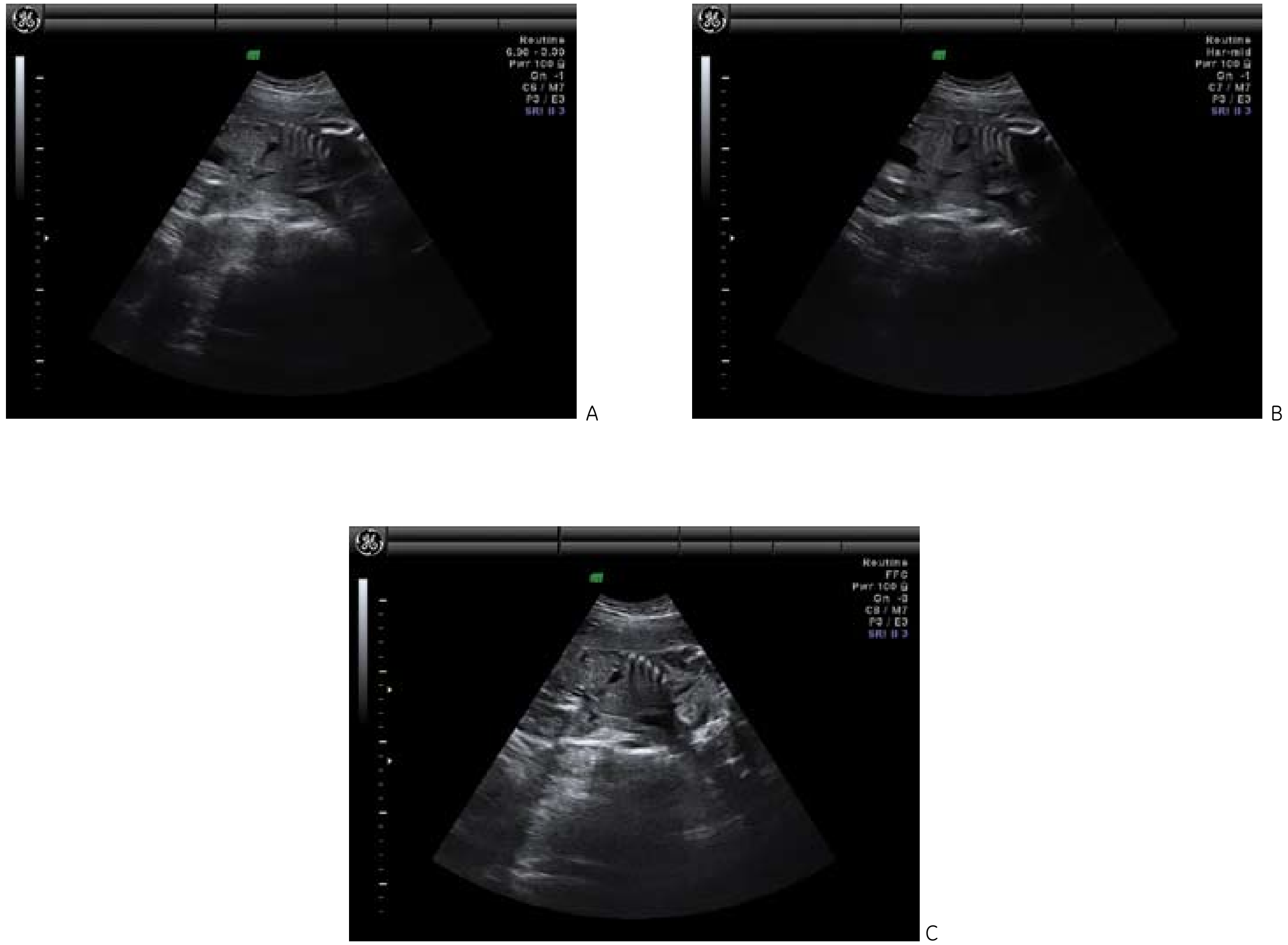

Figure 4
(A): Fundamental Imaging (B): Harmonic Imaging and (C): FCC

CrossXBeamCRI (CRI)

CRI is a spatial compounding technique that takes advantage of the properties of ultrasound imaging that artifacts and speckle are direction dependent. In this mode, pulses are transmitted both perpendicular to the acoustic window and in oblique directions (see Figure 5). Up to 11 pulses are correlated to form one CRI image. The procedure results in enhanced contrast resolution with better tissue differentiation andclear organ borders (see Figure 6). In addition, vessel walls and tissue layers are emphasized for easier recognition, and cysts appear with less acoustic shadowing.

The technique is extremely versatile: the number of CRI levels can be adjusted, and CRI can be combined with other 2D Voluson software features such as HI and SRI II, as well as with 3D features such as Spatio-Temporal Image Correlation (STIC) and Tomographic Ultrasound Imaging (TUI), both used in fetal heart imaging. CRI is available on all Voluson convex and linear transducers.

Applications

Obstetrics: Excellent boundary definition in first- and second-trimester cases.

Radiology: Thyroid, lymph nodes, breast lesions (early detection), testicles.

Musculoskeletal: Definition and structure in shoulder, knee and tendons.

Peripheral vascular: Sustained echogenicity of vessel walls.

Limitations

Can change the artifact behavior in the ultrasound image. For example, CRI can eliminate shadowing that clinicians are accustomed to seeing.

Case

In the breast lesion images below, the fundamental image is at the left, while the image on the right displays the same lesion with CRI and (SRI II) (see Figure 7). In the CRI image, the borders and tissue differentiation are much more pronounced.

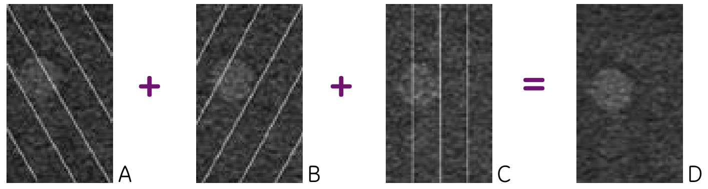

Figure 5
(A): Left steer (B): Right Steer (C): No steer (D): Compounded

Figure 6
Fetal profile without CRI (left) and with CRI at level 3 (right)

Figure 7
(A): Breast lesion without CRI (B): With CRI (level 3) and SRI II (level 3)

Speckle Reduction Imaging II

Ultrasound images suffer from an intrinsic artifact called speckle, created by reflections of an ultrasound pulse. Speckle, which gives images a granular appearance, degrades contrast resolution and obscures underlying anatomy. SRI II uses advanced, adaptive, real-time software algorithms to reduce speckle while retaining all anatomical markers, thereby enabling better visualization of organs, tissues, lesions, and borders.

SRI II also brings the capability of adaptive feature enhancement, which optimizes feature detection based on the size and orientation of physiological structures. A sophisticated algorithm smooths along boundaries and enhances contrast while preserving detail. SRI II enables clinicians to select various levels of speckle reduction (see Figure 8). This is important for accommodating individual user preferences and optimizing images in various applications. In addition, SRI II can be used as a post-processing tool and applied to stored cases.

Applications

Obstetrics: Measurements such as nuchal translucency, where reduction of haze can improve accuracy of caliper placement and results.

Gynecology: Subtle tissue differences including signs of irritable bowel syndrome.

Radiology: Smooth contrast-enhanced image quality, optimized for organs such as the liver, kidneys and spleen.

Limitations

The benefits of SRI II are independent of anatomy and patient habitus. Therefore, the primary limitation is building clinicians' awareness and confidence in SRI II, and willingness to move away from the traditional "pixelly" image. With tools like dual display, which provides a side-by-side view of fundamental and SRI II images, clinicians can observe the difference and quickly appreciate that SRI II does in fact remove speckle without degrading the underlying image.

Case

In this dual display of a uterine fibroid, the image acquired using SRI II, shows better internal characterization of the lesion (see Figure 9).

This dual display of a breast lesion demonstrates the combination of SRI II and CRI. The image with SRI II and CRI (right) results in reduced artifact in hypoechoic areas, with better border definition and improved internal characteristics of the lesion (see Figure 10).

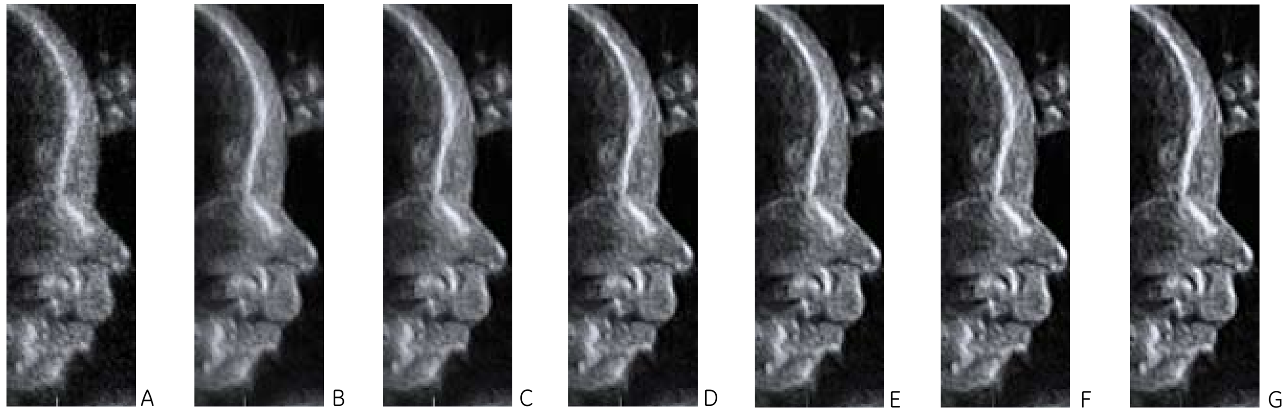

Figure 8
(A): Fundamental (B): SRI II 1 (C): SRI II 2 (D): SRI II 3
(E): SRI II 4 (F): SRI II 5 (G): SRI II 6

This sequence shows a progressive reduction in speckle from the original image (left) to SRI II level 6 (right)

Figure 9
Uterine tumor without SRI II (left) and with SRI II

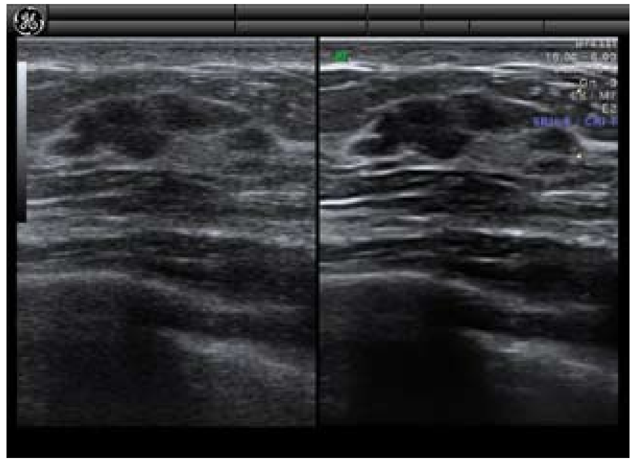

Figure 10
Breast lesion without SRI II and CRI (left) and with SRI II and CRI

Summary

2D imaging is the core function of an ultrasound system. Because clinicians manage unique cases and patients every day, they require ultrasound tools that will help them get the optimal image quality for every examination. GE's Voluson ultrasound systems deliver an advanced package of 2D imaging tools from harmonic imaging, frequency and spatial compounding to speckle reduction, that truly helps make better, more informed patient care decisions.

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