

Tissue Strain Analytics
Virtual Touch Tissue Imaging and Quantification
ACUSON S2000 Ultrasound System

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Introduction

Siemens ACUSON™ ultrasound systems feature a comprehensive range of tissue strain analytic applications that enable qualitative visual or quantitative value measurements of the mechanical stiffness (elasticity) properties of tissue. This new dimension of diagnostic information is not available using conventional sonographic imaging, and represents the most important development in ultrasound technology since the advent of Doppler imaging. Tissue stiffness information is complementary and independent from the acoustic impedance information provided by B-mode (grayscale) imaging as well as vascular flow information provided by Doppler imaging (**Figure 1**). Thus, tissue strain analytics provide information that is complementary to other ultrasound derived information in approaching diagnostic challenges (**Figure 2**).

Acoustic radiation force impulse imaging (ARFI) is a new tissue strain imaging technology that utilizes sound waves to interrogate the mechanical stiffness properties of tissue¹. Virtual Touch™ tissue imaging and Virtual Touch™ tissue quantification are the first and only commercially available applications implementing this technology.* These applications are available exclusively on the ACUSON S2000™ ultrasound system.

* Virtual Touch applications are not commercially available in the USA.

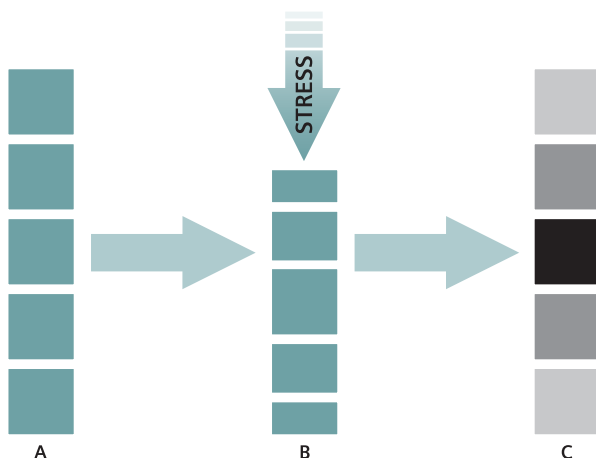
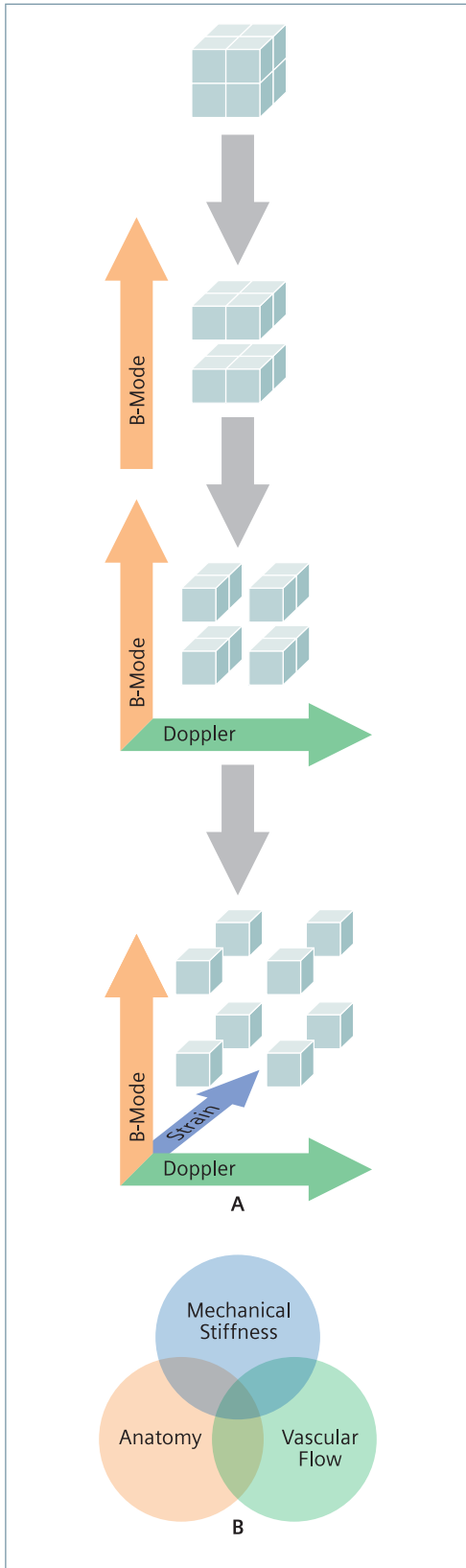


Figure 1. Adjacent tissue elements may appear identical using conventional B-mode or Doppler imaging (A). However, when a stress (axial force) is applied to these tissues, they may behave differently with some experiencing greater deformation than others (B). By comparing the baseline and stress image information, individual tissue elements may be labeled by their relative stiffness. A light shade indicates relatively soft (elastic) tissue, while a darker shade indicates relatively stiff (non-elastic) tissue (C).



Unlike conventional B-mode sonography, which provides anatomical detail based on differences in acoustic impedance, Virtual Touch imaging describes relative physical tissue stiffness properties. In this sense, Virtual Touch imaging is more similar to a physical palpation exam of tissue than conventional sonographic evaluation. In complement, Virtual Touch tissue quantification provides accurate numerical measurements related to tissue stiffness at user-defined anatomical locations. For example, a given lesion or structure can be qualitatively visualized for its overall stiffness relative to surrounding tissue as well as the relative stiffness of its internal structure. Subsequently, numerical measurements of the lesion can be made. Overall, Virtual Touch software is an advanced form of sonographic imaging and provides complementary information to a conventional ultrasound scan while benefiting from anatomical localization.

Technology Overview

It is important to understand that while ultrasound-based techniques are utilized by Virtual Touch software applications, the resulting information and source of tissue contrast are substantially different than conventional sonographic imaging. There are three general steps in the Virtual Touch software acquisition process. First, a baseline B-mode sonographic reference image is obtained. Second, a short (approximately 100 microsecond) acoustic “push” pulse is transmitted

Figure 2. Tissue strain analytics provide a new dimension of diagnostic information. Consider a group of diagnoses, represented by eight cubes, which must be separated (differentiated) using ultrasound information. Each dimension of information allows additional separation of diagnostic possibilities (A). Mechanical stiffness information can be combined with anatomical (B-mode) as well as vascular (Doppler) information such that the actual diagnosis is contained by the intersection of three dimensions of information (B).

through tissue. As this pulse travels through the region of interest, the tissue experiences a small displacing mechanical force. Depending on its specific stiffness properties, a given tissue will displace approximately one to 20 microns. While a soft tissue may experience a large displacement, a very stiff tissue may displace little or not at all. Once the push pulse has passed through, the tissue begins to relax towards its original configuration. Third, conventional sonographic tracking beams are applied during a short time interval (typically a few milliseconds). These beams provide data that is compared with the reference image as to compute tissue displacements resulting from the push beam.

Although ultrasound beams are utilized both to compress tissue as well as observe dynamic tissue behavior, Virtual Touch software applications operate within standard acoustic energy guidelines. Both tissue energy deposition as well as peak acoustic power are comparable to conventional ultrasound imaging and similarly regulated. This is made possible by the high sensitivity of the ACUSON S2000 system architecture for detection of the minute tissue displacements generated by the acoustic push pulse. Excessive transducer heating is automatically prevented by limiting the frequency and magnitude of push pulses. For each acquisition, Virtual Touch software applications consider parameters such as the region of interest (ROI) size and depth to compute a delay before the next push pulse is generated.

Technology Advantages

There are several advantages of Virtual Touch software compared with other methods of tissue strain imaging. Previously available methods require manual compression of tissue with the transducer or rely on physiologic motion within the body (cardiac, respiratory, etc.) These approaches may limit the depth and location of imaging and result in artifacts related to the global nature of the

compression force. Further, the resulting image may vary due to differences in the force application. For example, insufficient axial force may be transmitted to a deep soft tissue layer resulting in a false depiction as stiff tissue. In contrast, using Virtual Touch software applications, only the target tissue is “pushed,” and displacements within deep tissue are feasible. In addition, the local displacement force better penetrates tissues located deep to a stiff surface. Tissue surrounded by a low friction environment, or physically separate from its background, may also be imaged. Overall, compared with several other methods, there is increased contrast-transfer-efficiency² resulting in superior image quality, and increased reproducibility with decreased inter-operator variability.

Virtual Touch Tissue Imaging

A Virtual Touch software image is a qualitative grayscale map of relative tissue stiffness (elastogram) for a user-defined ROI (**Figure 3**). This information is computed by examining the relative displacements of tissue elements due to an acoustic push pulse. For a given elastogram image, bright regions depict tissue that is more elastic (less stiff) than dark regions. While a Virtual Touch software image may be displayed side-by-side with a corresponding conventional ultrasound B-mode image, apparent tissue boundaries may differ between the images as they rely on different tissue contrast mechanisms.

The Virtual Touch tissue imaging application forms an image by combining independently acquired multiple axial lines of tissue displacement information. Starting with the left most axial line within the ROI, a baseline conventional ultrasound signal description of the tissue is obtained. Next, a push pulse is applied along this line. Conventional tracking beams are applied along the same line to obtain the displaced tissue signal. The

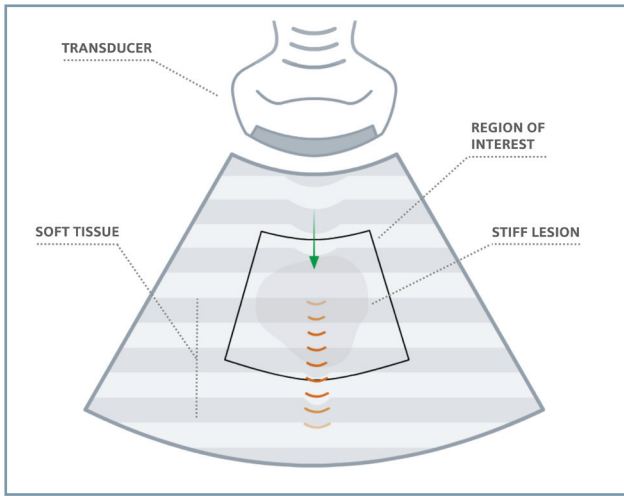


Figure 3. Virtual Touch tissue imaging utilizes acoustic push pulses (orange) and tracking beams (green arrow), sequenced across a user-defined region of interest, to generate an elastogram depicting the relative stiffness of tissue.

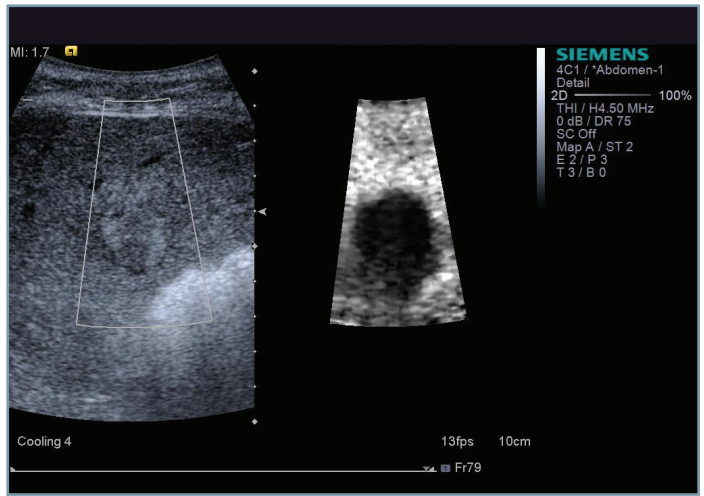


Figure 4. Virtual Touch imaging demonstrates a lesion which is more stiff (less elastic) than the surrounding tissue. The conventional ultrasound image (left) was utilized to define a region of interest around a subtle lesion for generating the elastogram (right).

baseline and post-push signals are compared using a cross-correlation algorithm. This allows computation of differences in tissue position, at each point along the axial line, between the relaxed and compressed states. The computed differences are related to the maximum displacement experienced at a given spatial tissue location due to the elastic properties of the tissue at that location. The more elastic a given tissue element, the more displacement it experiences. The above process is repeated for each axial line within the ROI as with a conventional B-mode scan. Finally, all computed displacements across the entire ROI are converted to an elastogram image depicting relative tissue stiffness (Figure 4).

Virtual Touch Tissue Quantification

In addition to qualitative imaging, ARFI technology may be utilized to measure a numerical value of shear wave speed³ as implemented by Virtual Touch tissue

quantification (Figure 5). In general, the more stiff a region of tissue, the greater a shear wave's speed as it travels through this region. Thus, the measured shear wave speed is an intrinsic and reproducible property of tissue. Shear waves are generated and travel perpendicular to an acoustic push pulse induced displacement of tissue much like ripples resulting from a stone dropped into a pond. Thus, in contrast to conventional axially oriented ultrasound waves, shear waves do not directly interact with the transducer. In addition, unlike conventional ultrasound waves, shear waves are attenuated approximately 10,000 times more rapidly, and thus require greater sensitivity to measure. However, as the shear wavefront travels through tissue, the generated displacements are detectable using ultrasound tracking beams. By observing the shear wavefront at several locations, and correlating these measurements with the elapsed time, the shear wave speed is quantified.

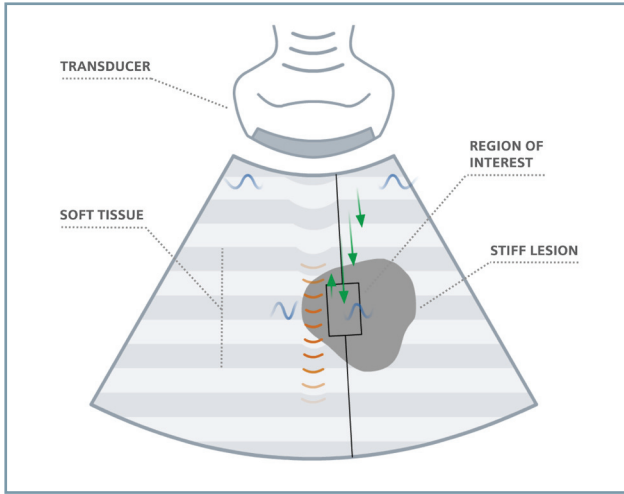


Figure 5. Virtual Touch tissue quantification utilizes an acoustic push pulse (orange) to generate shear waves (blue) through a user-placed region of interest. When detection pulses (green arrow) interact with a passing shear wave, they reveal the wave's location at a specific time, allowing calculation of the shear wave speed. This numerical value is related to the stiffness of the tissue within the region of interest.

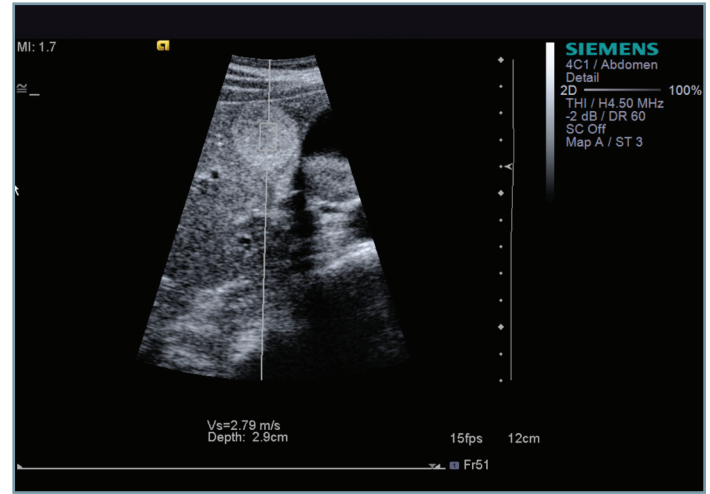


Figure 6. Using Virtual Touch tissue quantification, the shear wave speed through a hyperechoic liver lesion is easily measured. This value is related to tissue stiffness at the user-defined anatomical region localized using a conventional ultrasound image.

For Virtual Touch tissue quantification, an anatomical location for measurement is first identified using a ROI placed on a conventional ultrasound image. An acoustic push pulse is applied just lateral to this location, inducing a shear wave that travels through the ROI. Tracking beams, sensitive to greater than 1/100 the wavelength of sound, are applied adjacent to the push pulse path. These beams are continuously transmitted until the passing shear wavefront is detected. The time between generation of the shear wave and detection of the peak is utilized to compute the shear wave velocity. Multiple measurements are made for a given spatial location before a value is reported in order to ensure measurement quality (**Figure 6**).

Conclusions

Virtual Touch tissue imaging and quantification are the first and only commercially available implementations of acoustic radiation force impulse imaging. Through this modality, previously difficult or impossible elastographic examinations are made accurate and practical. Most importantly, Virtual Touch software technology enables a new dimension of tissue information to be applied for screening, diagnostic and therapeutic clinical applications⁴.

For more information on tissue strain analytics, please visit www.siemens.com/strain.

References

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Standalone clinical images may have been cropped to better visualize pathology.

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