

Touch Prime: Advanced ultrasound imaging with an extraordinary user experience

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Introduction

The CARESTREAM Touch Prime Ultrasound System is based on an all new computing architecture equipped to provide precise advanced front-end beam forming, novel imaging modes, and automated image optimization capabilities. Advanced ultrasound beamforming and post-processing technologies greatly benefit from access to increased computing power. Medical ultrasound imaging continues to seamlessly leverage advances from the consumer space, and the use of Graphic Processing Units (GPUs) in combination with highly-integrated front-end hardware is a prime example of this trend. Embracing this, the Touch Prime system is based on a new hardware architecture built from the ground up and equipped with game-changing ultrasound imaging technologies. When combined with an extraordinary user experience, **it makes the Touch Prime the next revolution in Ultrasound.**

The Touch Prime is targeted for Radiology, OB/GYN, Musculoskeletal (MSK), Vascular and general cardiac imaging applications. This whitepaper highlights some of the key underlying technologies available on the Touch Prime Ultrasound System.



SynTek Architecture: Next Generation Smart Beamforming

In conventional ultrasound systems, the time required to acquire ultrasound data is physically constrained by the sound propagation speed in the body. In soft tissue, this averages 1540 m/s. Conventional ultrasound systems have to wait for this sound propagation, during both transmit and receive, due to the serial nature of line-by-line data acquisition. As a result, these systems require the sacrifice of frame rate and overall speed, often forcing the clinician to choose between frame rate and image quality. For example, temporal resolution may be sacrificed for improved spatial resolution.

The acquisition speed limitation of conventional systems also causes a degradation of either frame rate or image quality when duplex modes such as color flow (Doppler imaging) is employed. This is because color Doppler techniques can require multiple pulses per scan line, and therefore frame rates are lower than those for comparable depth grayscale anatomic imaging. The problem, as noted earlier, is that conventional beamforming is physically constrained by the serial data acquisition method.

Another common implementation in modern conventional ultrasound scanners equipped with digital beamformers is the use of dynamic receive focusing but a fixed static transmit focus. With digital beamformers, the echo signals are continually focused as they are received by the transducer and thus the received beams are maintained in constant focus. This is done by constantly updating the beamformer focus delays as the echoes return from increasing depths. However, since image quality is a product of the transmit-and-receive focusing profile, the best image quality is typically obtained around the transmit focus where the beam width is narrowest.

In recent years, multizone imaging has been introduced and is widely available on commercial ultrasound systems. This approach is based on using consecutive transmissions along a given direction with the transmit focus placed at different depths, and blending the received beams from each of these transmissions together to form an image scan line. However, this approach compromises frame rate for improved image quality.

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The CARESTREAM Touch Prime Ultrasound System presents a paradigm shift from these conventional approaches by employing an all new system architecture that leverages integrated advanced GPU processing power and proprietary parallel beamforming hardware. The inherent data parallelism and high throughput offered by this combination is the basis for advanced beamforming algorithms. Together, the hardware and software forms the beamforming architecture introduced by Carestream as **SynTek architecture**.

SynTek architecture is a significant departure from the serial line-by-line acquisition approaches. With Syntek, a given tissue region is insonified in multiple directions from independent transmit firings. The echoes received by the transducer are coherently summed together, taking into account the difference in round-trip travel time from the transducer to the tissue location and back for each of the firings. Thus, by combining the information independently obtained from many such transmit events throughout the imaging region of interest, the SynTek architecture in effect synthesizes a transmit beam that is narrow not only at a single point or region in the image (around the transmit focus in conventional imaging), but over the entire spatial extent, leading to improved image quality.

In a conventional system, using such a transmit scheme with multiple transmit firings would have led to a reduction in frame rate. However, the parallel acquisition and real-time processing capabilities of the SynTek architecture leads to minimal compromise in frame rate at the cost of image quality.

Summary: SynTek Architecture

The performance advantages provided by the SynTek architecture are multiple:

- The image resolution and penetration is enhanced, since multiple beams at every depth location are coherently combined, leading to a better Signal-to-Noise ratio.
- Frame rates are increased due to a reduced number of transmits being used to create the image.
- Since multiple overlapping transmit beams are used to reconstruct a given scanline, the beam is focused over multiple depths simultaneously, in turn making the transmit focus position less critical as well. In color flow and Doppler imaging, SynTek architecture allows for more consistent visualization of subtle tissue contrast differences, while simultaneously improving the ability to see small structures. There is more information at depth as well as increased frame rates for improved visualization of moving structures.

Clinical Benefits of SynTek Architecture

- Uniform lateral resolution over the entire depth, making position of transmit focus less critical
- High frame rate while maintaining the spatial resolution
- Improved penetration (e.g. for deep abdominal imaging)

The image below is an abdominal scan of the liver acquired with the 6C2 transducer on the Touch Prime Ultrasound System.



This image illustrates superb spatial and contrast resolution throughout the entire image with uncompromised clinical detail.

Smart System Control (SSC)

Another path-breaking technology aimed at ultrasound workflow enhancement available on the Touch Prime system that harnesses the power of GPUs and parallel computing is Smart System Control (SSC). It is a **real-time optimization technique** implemented on the Touch Prime system to automatically adjust over 25 different imaging parameters (including some that are not under user control) to provide the user with optimal image quality. It essentially provides automatic system tuning beyond traditional keyboard/user controls. SSC technology has detailed insight and control of extended sets of parameters and their dependencies.

SSC technology can be used in B-mode, Color mode and Doppler imaging modes. To determine the optimal settings, the algorithm takes as input the user preference for frame rate or resolution and optimizes other system parameters automatically. The optimization is performed continuously in the background in real-time, and does not require the user to initiate it from the user console for each scan.

The following are examples of system parameters that SSC automatically adjusts during the system operation:

Ultrasound Mode	Parameters
B-mode	<ul style="list-style-type: none">• Line density• Number of focal zones• Number of transmit beams• Number of Compounding angles
B-mode + Color (Duplex)	<ul style="list-style-type: none">• B-mode & Color line density• Number of pulses transmitted in each waveform packet (shots per estimate)

SSC technology ensures constantly optimized images with limited user interaction, which results in improved workflow and diagnostic confidence. It has the potential to reduce exam times because there is no need to adjust the imaging parameters manually. The result is an optimized image with fewer touch-panel hard and soft key presses by the user. Taking it further, the intent is that for routine applications, SSC technology can lead to out-of-the-box optimized images with minimal manual changes needed from the user.

Beyond Imaging Performance

With the power of SynTek and GPU processing, the CARESTREAM Touch Prime Ultrasound System is only using a small fraction of its potential power at first release. In conjunction with its programmable touch user interface, the system is an ideal platform for upgrades without the need for major hardware changes. As Carestream continues to innovate with enhancements to imaging performance and new features, the system lends itself to easy upgradeability and has power for further technology-driven innovative applications.

The following are examples of such innovative applications available at first release.

Smart Flow Imaging

To assess blood flow in arteries and veins, Doppler ultrasound uses the frequency shift that occurs when sound waves bounce off a moving object. Such images are used to uncover blockages and clots, the narrowing of blood vessels and congenital vascular malformations. In color Doppler imaging, echo measurements are displayed as colors that indicate the speed and direction of blood flow. They are used to identify narrowed blood vessels, for example, and the tiny “jets” of blood associated with vascular anomalies. Power Doppler imaging is even more sensitive than color Doppler, visualizing blood flow through tiny vessels such as those that feed tumors in the thyroid and scrotum, as well as lesions just below the skin. Spectral Doppler technique calculates and then graphs the velocity of blood flow according to the distance blood travels over time. Ordinary color and spectral Doppler ultrasound measures the velocity of flow components toward or away from the transducer. It uses the angle of the ultrasound beam relative to the flow direction to calculate the actual flow velocity through the vessel.

In current conventional implementations, the accuracy of Doppler computations depends on precise knowledge of the direction of the ultrasound beam and direction of the flow in the vessel (and the angle α between them).

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As the following Doppler equation indicates, when the ultrasound beam is perpendicular to the vessel (90°), this computation is impossible, because there is no flow component in the direction of the beam. In effect, the measurement is impossible when the insonation angle is over 60°, because then small errors in measuring the two directions lead to large discrepancies in the results.

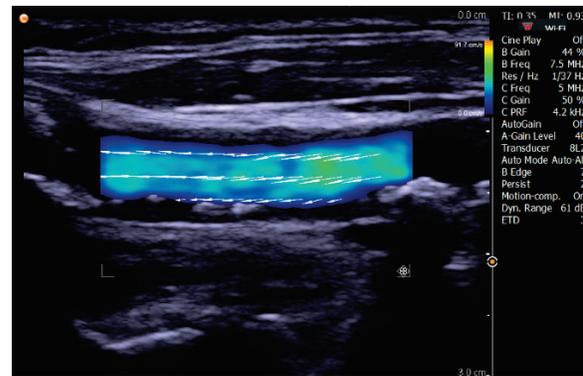
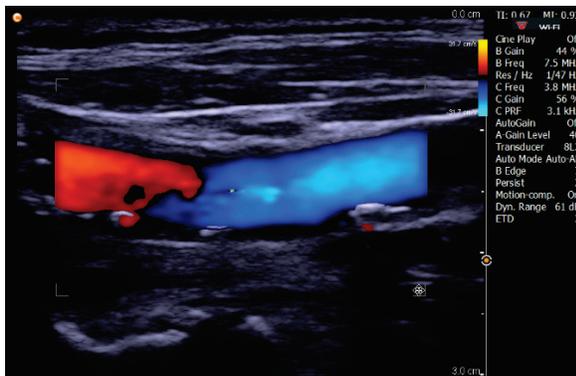
$$\text{Doppler frequency}(f_d) = \frac{2 \cdot f_t \cdot V \cdot \cos\theta}{c}$$

f_d = doppler shift
 f_t = transmitted beam
 c = speed of sound in tissue
 V = velocity of blood flow
 θ = angle of incidence between the ultrasound beam and the direction of flow.

Smart Flow imaging is a ground-breaking technology available on the Touch Prime Ultrasound System that has the potential to revolutionize the workflow for many Doppler ultrasound applications. In addition to revealing flow pattern details, it saves valuable time and makes the exam much easier. The new proprietary Smart Flow method **visualizes blood flow in all directions, independent of imaging angle**. It uses a technique called transverse oscillation to overcome the angle

limitations of ordinary Doppler ultrasound. It creates an effective component of the ultrasound oscillation perpendicular to the transmitting beam – an oscillation in the transverse direction (Jensen JA 2001; Jensen JA, Munk P 1998). Smart Flow technology generates a 2D interference pattern in the received ultrasound signal. This allows the system to calculate not only the axial component of the velocity (as traditional color Doppler), but also the transverse component. Therefore, Smart Flow technology **eliminates the angle dependence and enables both the detection and visualization of complex flows**.

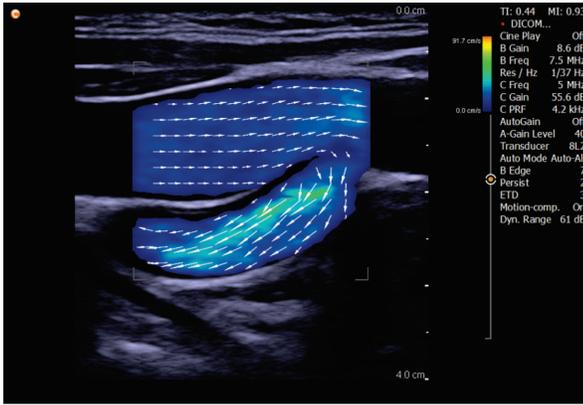
To display the information from Smart Flow technology on the Touch Prime platform, color coding and/or arrows are used. The length of the arrow, in addition to the color, indicates the magnitude, and the orientation of the arrow indicates the flow direction. The figures below illustrate a side-by-side comparison between conventional color flow imaging and the new Smart Flow technology in a carotid artery scan. The conventional color flow (left) produces drop-outs (regions with no flow) at locations within the vessel where the flow is oriented perpendicular to the acoustic beam (with no steering or angling of the color box). For the same anatomy, the Smart Flow image (right) displays continuous and robust flow information throughout the entire lumen, even when the flow is perpendicular to the acoustic beam.



Comparison between conventional color flow (left) vs. Smart Flow (right) imaging in a carotid artery scan

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The figure below illustrates a Smart Flow image of the jugular vein (top) and carotid artery (bottom) in a normal volunteer acquired with an 8L2 transducer. The arrows indicate opposite flow directions, with longer arrow lengths towards the middle of the carotid artery lumen representing higher velocities.



Smart Flow image of a jugular vein and carotid artery with the arrows representing direction and velocity magnitude

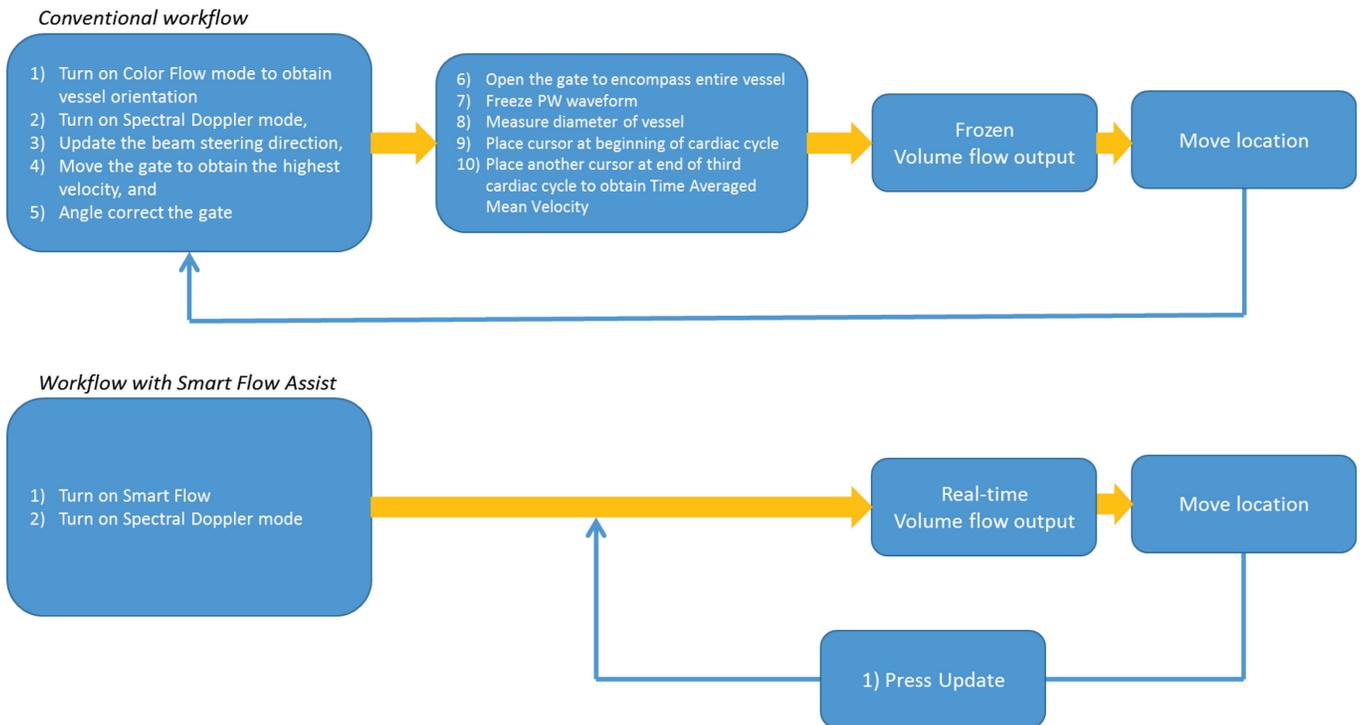
In conclusion, Smart Flow technology provides an intuitive visual representation of flow in all directions, making it well suited to visualize transverse flow and complex flow patterns including turbulence. The measurements are angle-independent. It enables a faster workflow since the overall

hemodynamic view is available without having to steer. The results are more consistent with less clinician dependence.

Smart Flow Assist

Spectral Doppler imaging is commonly performed to quantify the flow profiles in the blood vessels. The measurement is displayed as a waveform trace, depicting the velocity distribution (profile) at the given spatial location as a function of time. The typical steps involved in obtaining a velocity profile include: 1) Turn on Color Flow mode to obtain the orientation of the vessel, 2) Turn on Spectral Doppler mode, 3) Update the beam steering direction, 4) Move the gate to obtain the highest velocity, and 5) Angle-correct the gate. The above steps require manual effort by the user, and moreover steps 3 to 5 have to be repeated with movement of the transducer. Contrary to this conventional mode of operation, the Smart Flow Assist technology **eliminates the need for repeated manual adjustments**. With the proprietary functions in Smart Flow Assist technology, the software automatically updates the beam steering, gate position and angle correction. It is updated at all times, even when the transducer is moved.

The benefits of Smart Flow Assist technology are even more pronounced when measuring volume flow (VF). In this situation, the workflow to obtain VF is reduced from 10 steps (for a VF on a frozen image - and 10 more for every new location) to 2 steps (and one for every new location).



Conclusion

The CARESTREAM Touch Prime Ultrasound System provides several advanced ultrasound technologies, leveraging advanced GPU processing power for enhanced imaging performance. It incorporates a next-generation beamforming approach, leading to simultaneous improvement in frame rate and spatial resolution compared to conventional systems and

automation of ultrasound scan settings that results in improved workflow efficiency. These novel technologies, when combined with exceptional user experience features such as an all-Touch control panel, a thoughtful system design around ergonomics, and one-touch transducer activation, makes the Touch Prime a system of choice for Radiology, OB/GYN, Musculoskeletal (MSK), Vascular and general cardiac imaging applications.

Ajay Anand is a member of the ultrasound R&D team at Carestream Health. He has more than 10 years' experience leading the development of novel ultrasound technologies, and is a co-inventor of more than 20 patent filings in the field of medical ultrasound.

References

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