White paper

Slow flow state

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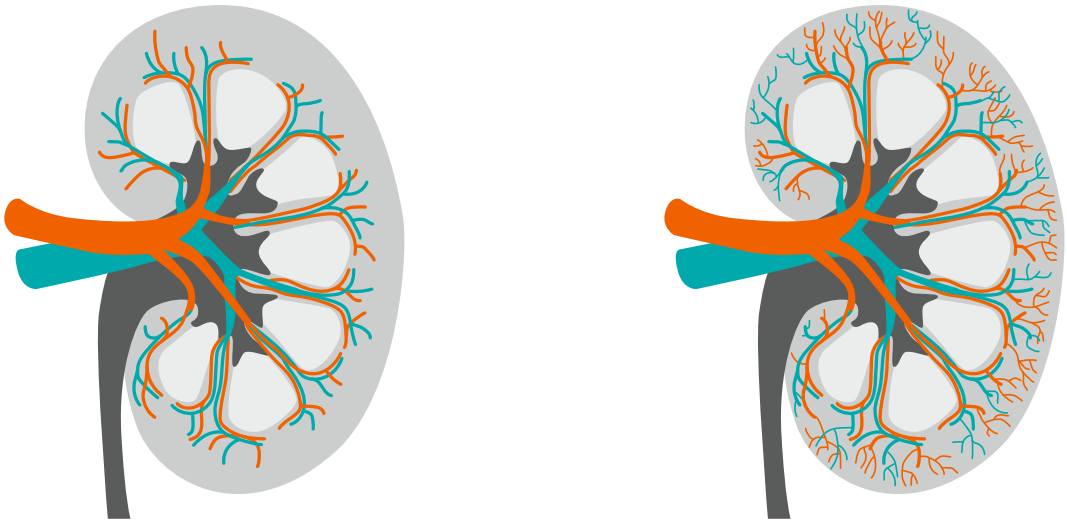


Figure 1: Visualized kidney vasculature using conventional Doppler (left) and Slow flow (right). While conventional Doppler easily demonstrates the flow in larger vessels within the kidney parenchyma, it is unable to identify flow in the small lower velocity vessels in the periphery. When the Slow flow Doppler technology is enabled, the lower velocity microvascular branches are easily identified in the peripheral parenchyma.

Introduction

Color Doppler technology can allow a user to determine presence or absence of blood flow as well as direction information and velocity. This technology, however, carries inherent limitations to sufficiently visualize smaller, low flow vessels. Small, weaker signals can be lost from the surrounding signal clutter or rejected as noise by filters within the system which remove this information altogether. With these challenges in mind, Siemens Healthineers developed a new color Doppler visualization technique that is specifically directed to address conventional Doppler limitations. This new technique is known as Slow flow Doppler state. Slow flow uses an intelligent algorithm combined with smart system filters to detect and separate the weaker signals. Once detected, these signals are amplified and used to help improve smaller, low flow vessel visualization. Compared to conventional color Doppler, Slow flow state allows users to easily visualize more vessels that are smaller and also see deeper into tissue[1] **(Figure 1)**.

[1] *Siemens Healthineers user survey*

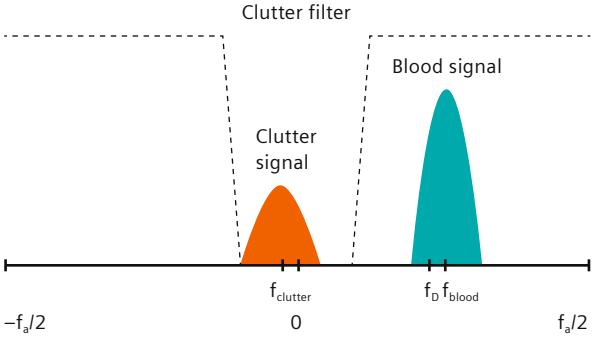
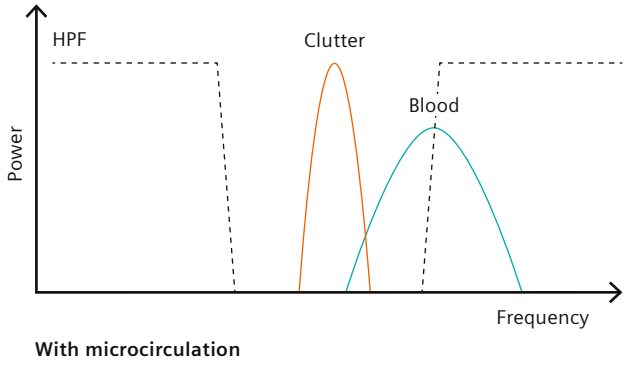


Figure 2: Conventional Doppler filters can successfully distinguish and separate clutter and flow.



With microcirculation

Figure 3: With microcirculation, weaker or slower blood flow signals may blend in with the surrounding stronger signals. When blended with clutter, these signals are not easily separated and can be lost or rejected as noise.

The background principle behind Slow flow

Medical ultrasound imaging is widely used in real time to detect and display blood flow in the human body. Ultrasound beams are transmitted into the body repeatedly at a predefined interval. The inverse of the interval is called pulse repetition frequency (PRF). A predefined number of the ultrasound pulses are grouped into a set of samples called ensembles. A wall filter is applied to the ensembles to separate flow signal from clutter based on flow velocity derived from Doppler phase shift. Conventional Doppler methods make use of a wall filter to remove clutter from the Doppler image.

Conventional Doppler filters work well when clutter and flow are well separated **(Figure 2)**. As flow becomes weaker or slower, it blends into clutter and becomes more and more difficult to extract out of clutter **(Figure 3)**. If the signals are not identified and extracted, they can be rejected by the wall filter as being noise, thus the signal is lost from the image. The goal of the Slow flow state is to extend the capabilities of conventional Doppler techniques to smaller vessels or slower blood flow in the Color Doppler Energy (CDE) mode where the strength of flow signal is reported but not the velocity.

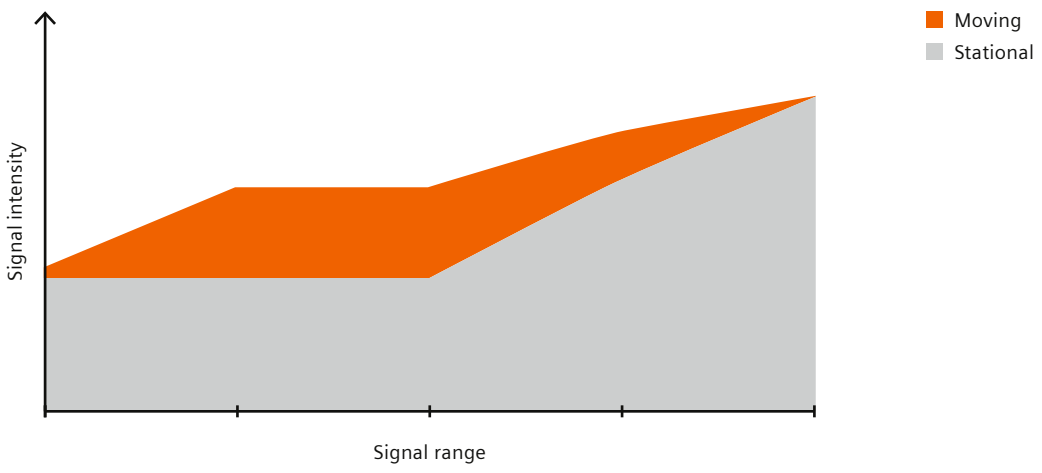


Figure 4: Separate moving signal from stationary signal. In this example, there are only two probability of being flow, 0 and 1.

Slow flow

Flow signals exist throughout a signal range, thus any given signal could be a composite of moving signal and stationary signal. In order to accomplish the goal of extracting a flow signal out of clutter, smart filters have to be in place to differentiate various flow from tissue. First, a novel self-constructive wall filter decouples motion signal from the stationary signal **(Figure 4)** over the entire signal range. This is accomplished by breaking down the signal into components which are ranked according to their possibilities of being clutters or flows. By doing this, the novel wall filter optimally labels flow which could be mixed with clutter and would be otherwise excluded by Doppler velocity cutoffs.

The moving signal then passes through an adaptive filter. The adaptive filter selectively detects and amplifies smaller or weaker flow signals to make them more pronounced and thus more easily detected. At the same time, the filter curbs motion artifacts and any overflowing stronger flow signal **(Figure 5)**. The results further go through a stochastic process to suppress flashes and to sustain the true flow signal **(Figure 5)**. The combined effects of those filters, together with longer ensembles and lower PRF, make it possible for the Slow flow state to detect smaller flow, slower flow, and more vessel branches into the tissue than conventional Color Doppler mode **(Figure 6, Figure 7)**.

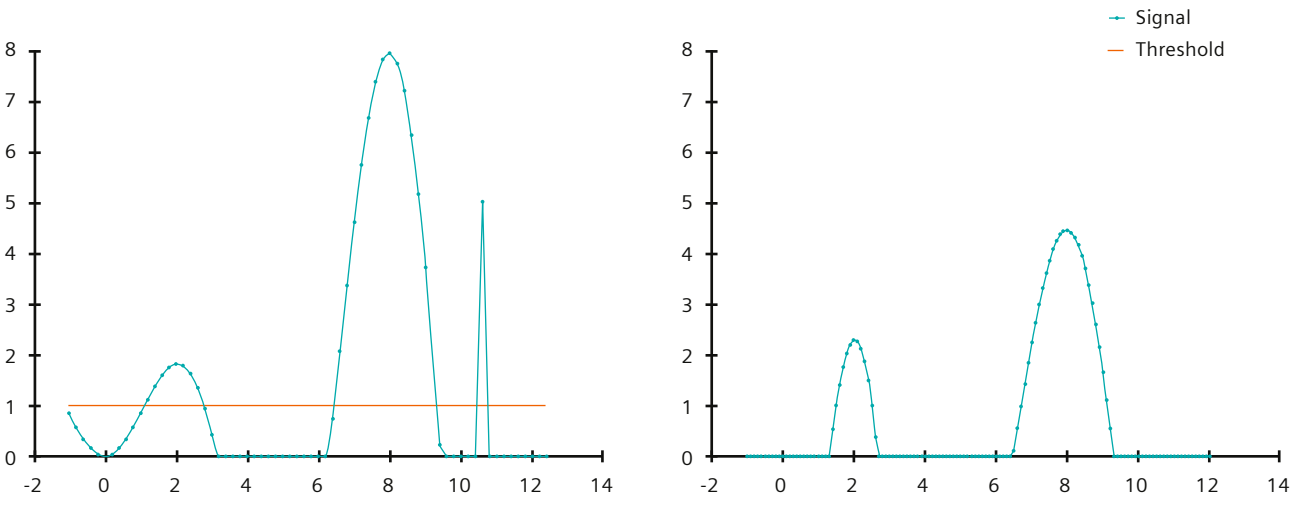


Figure 5: Moving signal (left) is further processed to amplify smaller flow, curb overflow and suppress flashes (right) with thresholds from adaptive algorithms.

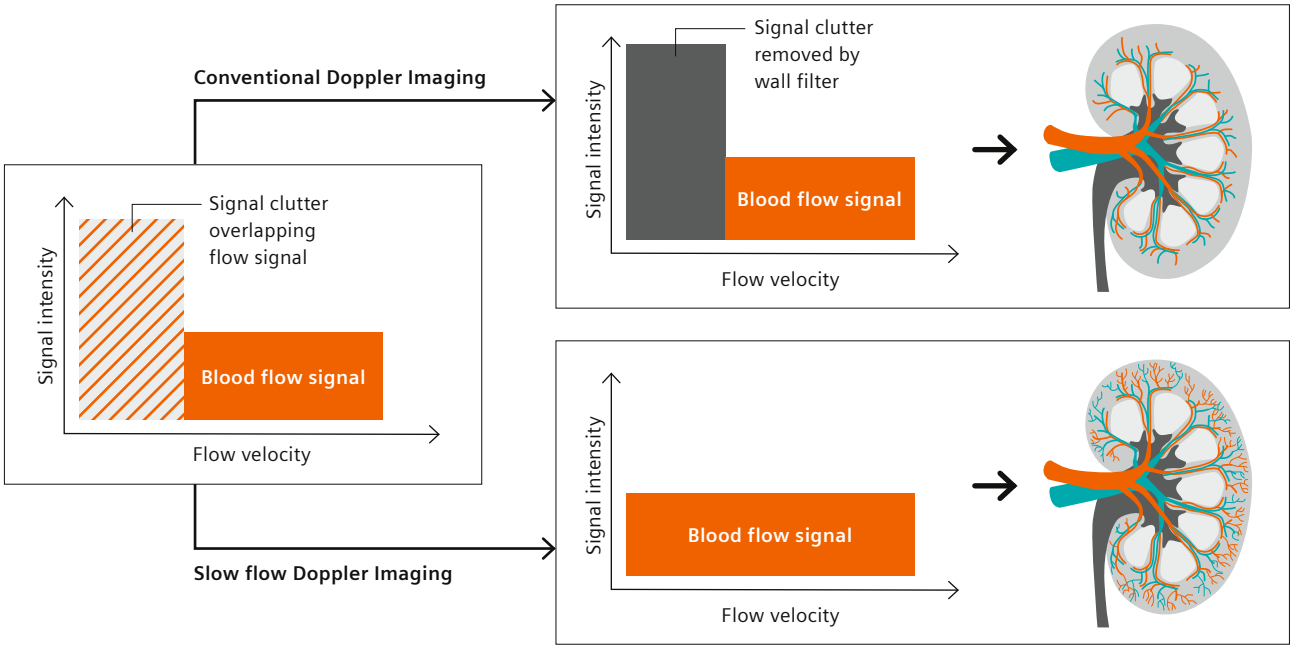


Figure 6: Tissue motion artefacts result in clutter that overlies the low velocity component of the blood flow Doppler signal. Conventional Doppler imaging employs the use of wall filters that remove this clutter. This removal cleans up the displayed Doppler signal however it also results in a loss of the low velocity components buried in the clutter. Slow flow Doppler imaging uses smart filters that can differentiate the motion artefact from the low-velocity signal buried within it. The resulting blood flow signal contains both weak and strong echoes and thus displays smaller, low-flow vessels within the ultrasound image.

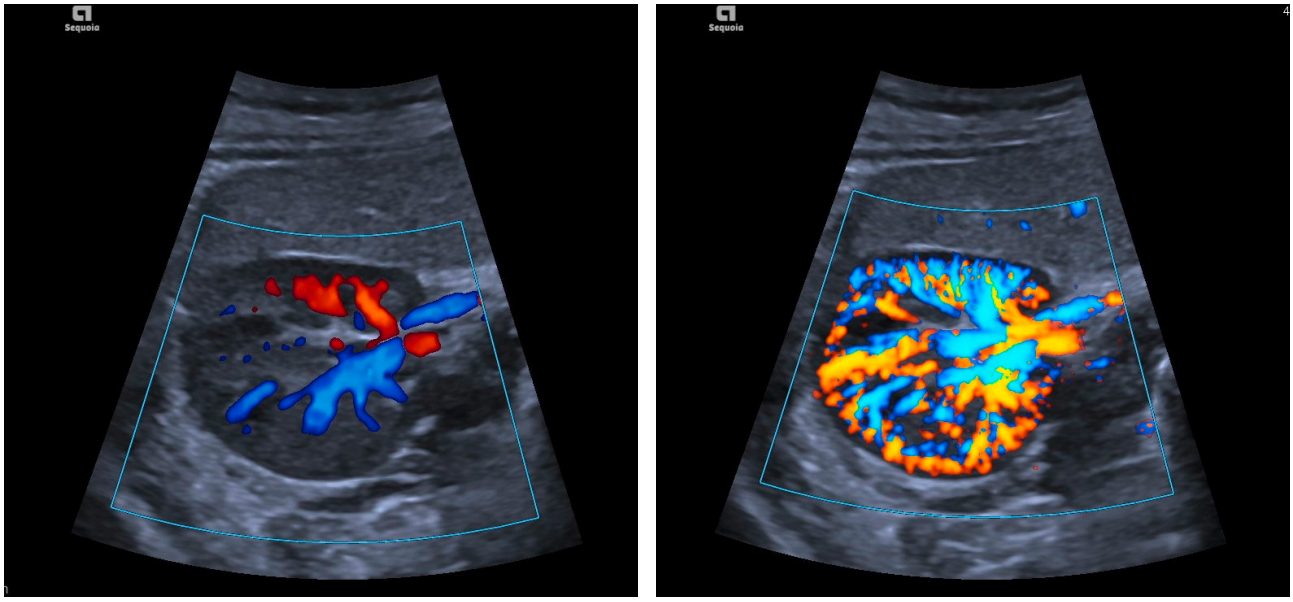


Figure 7: Image of the kidney using conventional color Doppler (left) and Slow flow Doppler (right).

Conclusion

There is, of course, always challenges to overcome when processing a great number of signal components used to generate the ultrasound image. Longer ensembles and slower PRF increases observation time which helps magnify flow signal. These longer ensembles, however, adversely affect frame rate. The ACUSON Sequoia ultrasound system's powerful front-end compensates for the acquisition time with parallel receive channels which yields good frame rates. Moreover, despite the fact that the smart filters are very computation-intense, the computation load is handled gracefully by the state-of-the-art computing engines on the ACUSON Sequoia ultrasound system. Overall, Slow flow provides information-rich images with a very good responsiveness to user operations.

Built on the advanced ACUSON Sequoia ultrasound system platform, the Slow flow state supplements conventional Doppler techniques to detect a broader range of flow signals. It employs sophisticated filters which extract flow out of clutter by motion filtering, adaptive signal enhancement and flash suppression. As a result of this advanced engineering technique, Slow flow is able to visualize smaller, slower flow vessels, as well as visualize these challenging vessels further into the tissue being imaged.

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