Overcoming Angle Dependence in Doppler Ultrasound

Author: Ajay Anand, PhD

Carestream's Smart Flow technology enables detection and visualization of complex flows independent of the Doppler angle

Looking at a compass, a difference of one degree seems inconsequential. Yet being off one degree on a flight path and traveling 60 miles an hour will put a plane 1 mile off course after 60 minutes. And in conventional Doppler imaging of blood flow, the wrong angle can lead to large discrepancies in results.

Ordinary color and spectral Doppler ultrasound measure the velocity of flow components only toward or away from a transducer. In conventional implementations, they use the angle of the ultrasound beam relative to the flow direction to calculate the actual flow velocity through the vessel. Thus, 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).

As the following Doppler equation illustrates, 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.

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

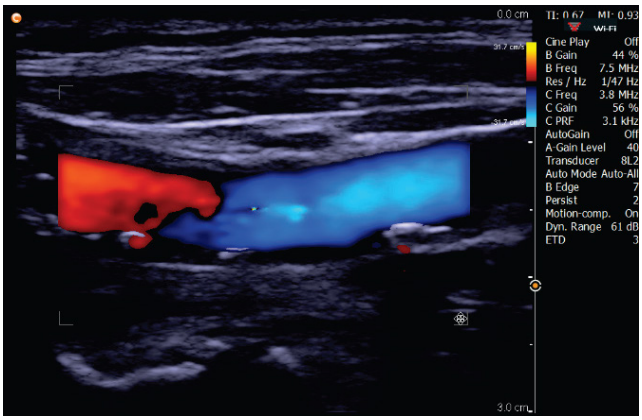
f_d = doppler shift
f_t = transmitted beam
c = speed of sound in tissue
V = velocity of blood flow
θ = angle of incidence between the ultrasound beam and the direction of flow.

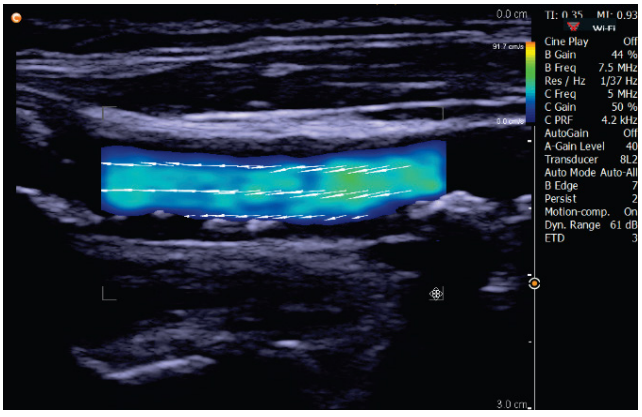
In effect, the measurement is impossible when the insonation angle is over 60° because small errors in measuring the two directions lead to large discrepancies in the results. Additionally, conventional color flow only measures flow velocity along the acoustic beam direction, which results in limited uni-directional measurement.

Carestream's new Smart Flow imaging technology eliminates the transducer angle limitations of ordinary Doppler ultrasound. The proprietary Smart Flow method can visualize and measure velocity even when flow is perpendicular to the acoustic beam. The resulting measurements are angle independent, and hence less prone to measurement error. Additionally, it visualizes blood flow in all directions – including axial and transverse – providing more comprehensive information about hemodynamics for stronger clinical diagnosis.

Color coding and arrows automatically display the information from Smart Flow technology on Carestream's Touch Prime Ultrasound platform. The length of the arrow, in addition to the color, indicates the magnitude. The orientation of the arrow indicates the flow direction.

The figures below illustrate a comparison between conventional color flow imaging and the new Smart Flow technology in a carotid artery scan. The conventional color flow (top) 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 (bottom) displays continuous and robust flow information throughout the entire lumen, even when the flow is perpendicular to the acoustic beam.





Smart Flow technology shows flow in all directions

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. This makes it well suited for clinical applications such as evaluation of hemodialysis vascular access (AV fistulas and grafts), monitoring TIPS and quantification of complex flow patterns in the presence of stenosis.

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Additional functionality can be gained with Carestream's Smart Flow Assist technology. Its proprietary functions eliminate the need for repeated manual adjustments like beam steering, gate position and angle correction – even when the transducer is moved. Smart Flow Assist also reduces the workflow to obtain volume flow from 10 steps to 2. Learn more about Carestream's advanced beam forming and post-processing technologies at www.carestream.com/touch.

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.

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