Doppler Aliasing

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This is the third in a series of articles on ultrasound physics and instrumentation in the Echo Rounds section.[1,2] In a previous description of the principles of spectral-Doppler instrumentation,[2] we discussed the ability of pulsed-wave (PW) Doppler instruments to locate the origin of received echoes (range resolution). The purpose of this article is to discuss a consequent limitation of PW-Doppler technology, the phenomenon of aliasing, and how it can be avoided.

PW-Doppler measures blood flow or cardiac tissue velocities at a precise location. This ability to localize measured velocities is dependent upon each pulse being transmitted and received before the next pulse is emitted. The resulting limit in emitted pulses per second (the pulse-repetition frequency, or PRF) introduces a fundamental limitation of pulsed-Doppler instruments, that of aliasing. Aliasing is an inability to accurately represent information due to an insufficient sampling rate[3] (Fig. 1). When the PRF is less than twice the peak Doppler shift frequency (Nyquist limit), aliasing occurs and is manifested as an inaccurate representation of the speed and direction of rapidly moving red blood cells (Fig. 2).

Clinical Avoidance of Aliasing

In order to display complete velocity spectra, aliasing must be avoided. As the Doppler shift frequency is proportional to emitted ultrasound frequency, a relatively low emitted ultrasound frequency will reduce the likelihood of aliasing.[1] Current-generation ultrasound machines can be programmed to default to a relatively low emitted frequency of ∼2 MHz when Doppler applications are employed.

With spectral-Doppler instruments, the zero-velocity baseline is positioned by default so that equal blood flow or tissue velocity ranges (the peak of which is the Nyquist limit) are displayed above and below the baseline. If aliasing is present, it may be possible to display the entire velocity spectrum by merely shifting the zero-velocity baseline, which increases the velocity range of one of the measurement channels (Fig. 3). If maximal shifting of the baseline does not eliminate aliasing, then the PRF must

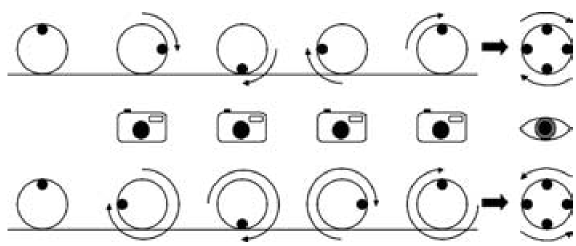

Figure 1. *The phenomenon of aliasing. Both wheels rotate in a clockwise direction. A picture is taken of the top wheel every one-quarter cycle. If those pictures are displayed consecutively in rapid fashion, as in a movie, the speed and direction of the rotating wheel is accurately portrayed to the naked eye. The bottom wheel rotates three-quarters of a cycle between pictures. As a result, the wheel appears to be rotating counterclockwise when the resulting movie is viewed. This inaccurate representation of information (aliasing) occurs because the frame rate of the camera is less than half the rate of rotation of the wheel.*

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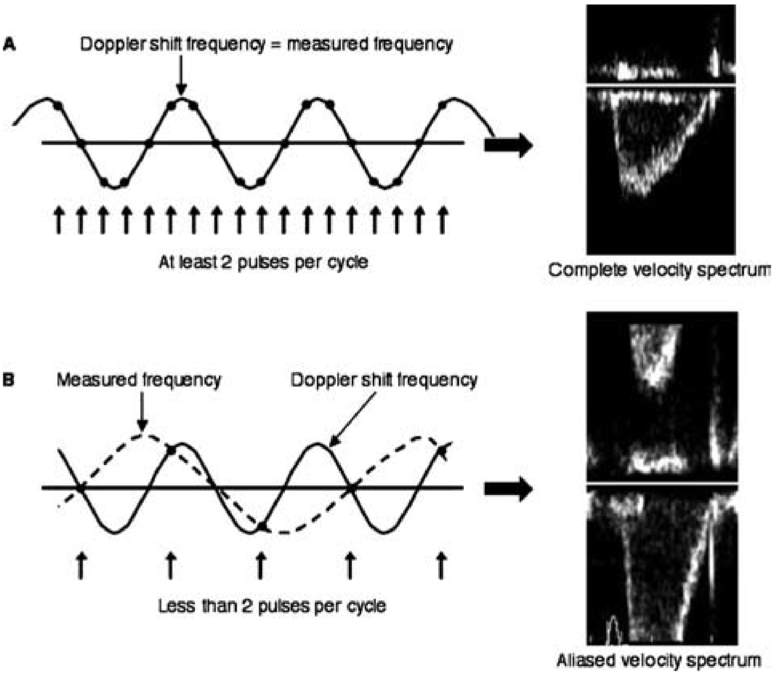

Figure 2. *The cause and appearance of Doppler aliasing. Each time a pulse is emitted from the transducer (arrows) represents a sampling of the Doppler shift frequency. (A) The Doppler shift frequency (and therefore velocity) is accurately represented if there are at least two pulses during each cycle of the Doppler shift frequency signal (i.e., pulse-repetition frequency ≥ 2 × Doppler shift frequency). The highest velocity that can be measured (the Nyquist limit) is therefore equal to half the pulse-repetition frequency. (B) If there are less than two pulses per cycle of the Doppler shift frequency signal, the measured frequency (and therefore velocity) underestimates the true Doppler shift frequency (velocity). The aliasing that results is manifested as a wraparound of the Doppler velocity spectrum into the opposite measurement channel, with an inability to display the complete spectrum.*

be increased. This is typically achieved by using the scale function to increase the PRF, which in turn increases the range of measurable velocities.

If aliasing remains despite setting a maximal PRF, one may use continuous-wave (CW) Doppler. As CW Doppler involves a continuous transmission and reception of ultrasound, aliasing will not occur, and there is virtually no limit to the measurable peak velocity. However, CW Doppler cannot localize reflector velocities (range ambiguity), therefore PW Doppler is necessary when velocity must be measured at a precise location.

Positioning the PW-Doppler sample volume at relatively greater depths automatically decreases the PRF, as emitted pulses require more time to return before the next pulse is emitted.

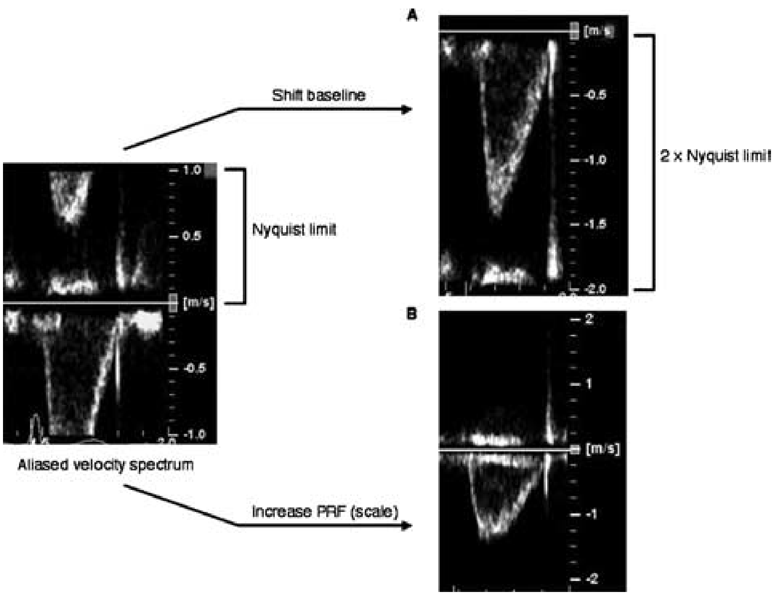

Figure 3. *Eliminating aliasing. When aliasing is present, a complete velocity spectrum may be obtained at average depths with conventional pulsed-wave Doppler by either or a combination of two methods. (A) Shifting the zero-velocity baseline is an electronic cut and paste method that assigns a greater measurable velocity range to one of the measurement channels, effectively increasing the Nyquist limit. (B) Aliasing can be eliminated by using the scale function to increase the pulse-repetition frequency (PRF), and therefore the measurable velocity range.*

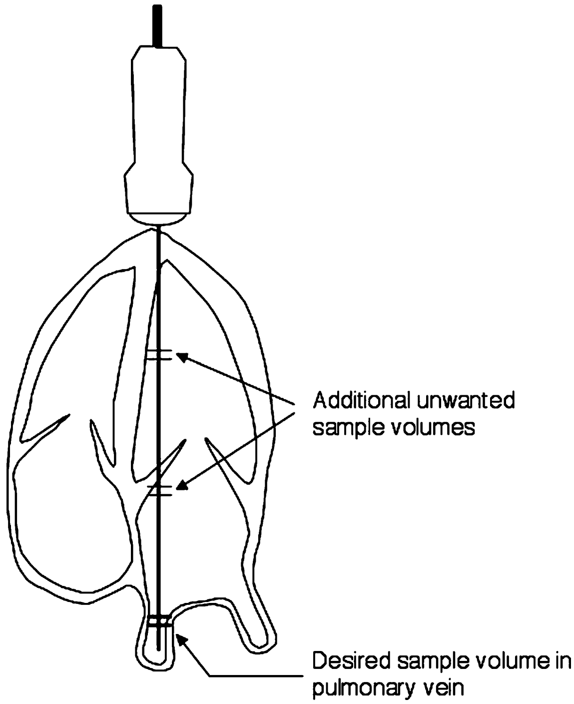

Figure 4. *The use of high-PRF Doppler to measure pulmonary vein velocities in the apical four-chamber view. In large patients, the pulsed-wave-Doppler sample volume is positioned at a relatively great depth, resulting in a reduced PRF and a greater susceptibility to aliasing. With high-PRF Doppler, more than one pulse is allowed to travel at a time, permitting an increased PRF and a reduced likelihood of aliasing. For each additional concurrently traveling pulse, an extra "unwanted" sample volume appears, thus introducing a degree of range ambiguity. PRF, pulse-repetition frequency.*

Consequently, aliasing is more likely to occur, thus limiting the measurable velocity range. To be able to measure complete PW-Doppler velocity spectra at greater depths, high-PRF Doppler is used.

High-PRF Doppler

High-PRF Doppler increases PRF, allowing higher velocities to be recorded. This requires that more than one pulse travel concurrently, thus introducing range ambiguity. The presence of simultaneously propagating pulses is accompanied by the display of an extra sample volume on the ultrasound screen for each additional pulse (Fig. 4). Because the distance to each sample volume is a multiple of the distance to the shallowest sample volume, the period of time during which the ultrasound machine "listens" for returning echoes corresponds to each of the displayed sample volume locations.[4] Thus, some degree of range resolution is maintained. However, a frequent drawback of high-PRF Doppler occurs when trying to measure pulmonary vein velocities in the apical four-chamber view at a greater than normal depth. Use of this Doppler modality commonly results in an extra sample volume positioned at the mitral valve level, which causes the left ventricular inflow velocity spectrum to dominate the display.

In summary, we have discussed Doppler aliasing and how it can be avoided. In order to accurately display the desired velocity spectra, one must optimally employ appropriate Doppler modalities, while maintaining an awareness of potential pitfalls.

References

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