Kỹ thuật và nguyên lý Doppler

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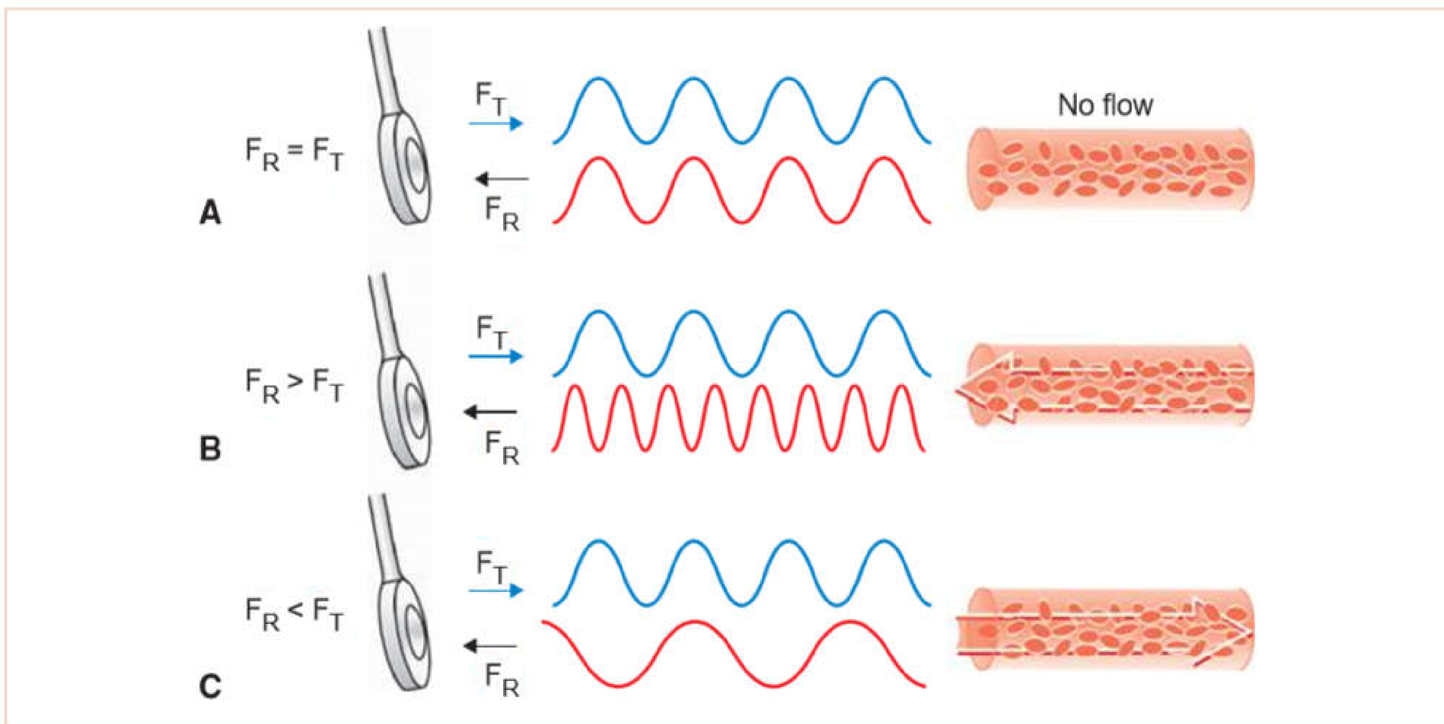
Detecting blood flow



A: The reflected echoes from a stationary target are of the same frequency as the transmitted signal. **B**: Objects such as red blood cells moving toward the transducer compress the sound signal, and the reflected frequency is increased. **C:** When red cells travel away from the transducer, the frequency of the reflected echoes is decreased. FT, transmitted signal frequency; FR, reflected signal frequency.

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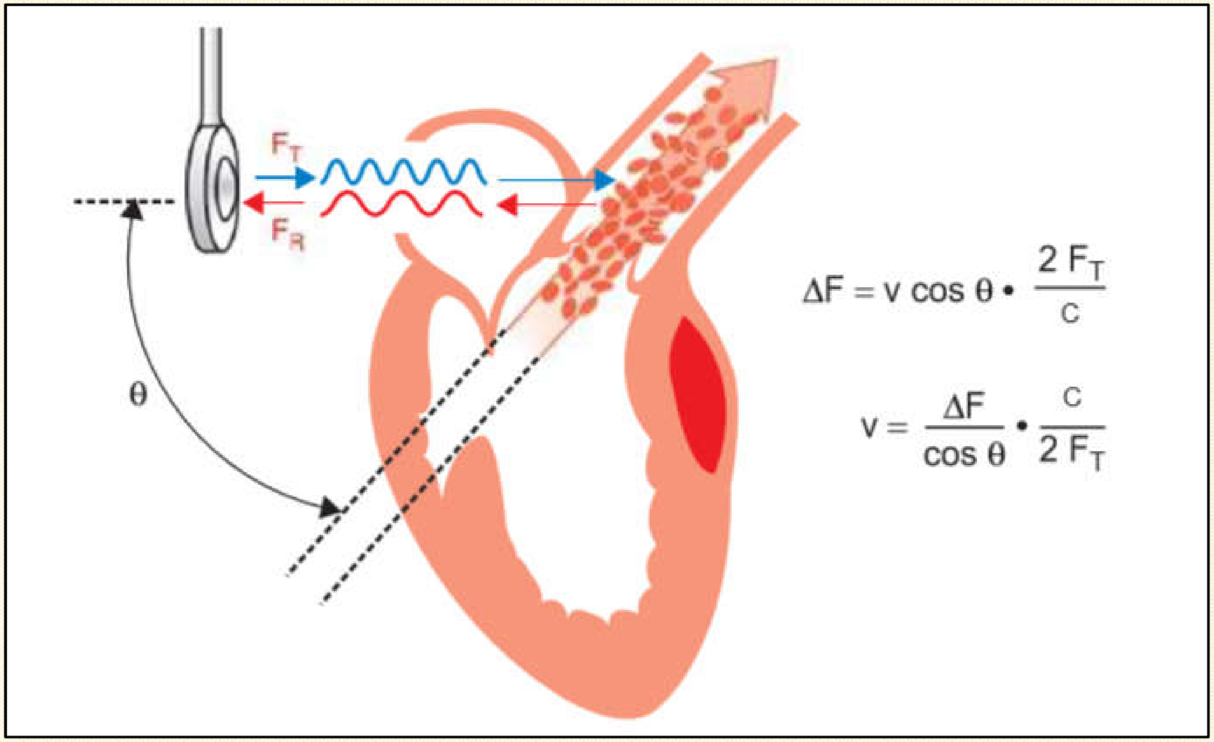
Doppler equation: Linking the Frequency Shift to Velocity



$$\Delta f = v \times \cos\theta \times 2f_t/c$$

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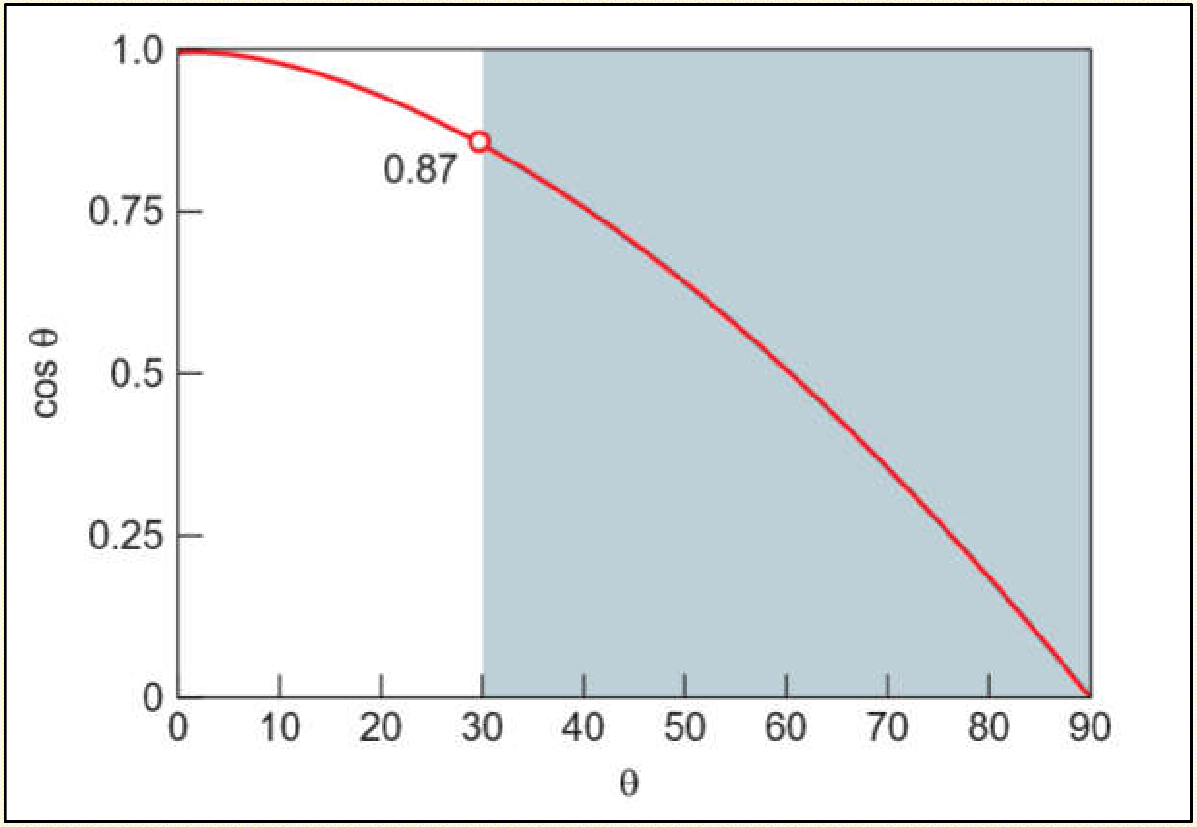
Cosine relationship



Most devices default to a simplified Doppler equation in which cos θ is ignored, with the assumption that the Doppler beam is nearly parallel to the blood flow so that the cos θ factor is negligible. However, at angles between beam and blood flow greater than 30 degrees, a precipitous drop in the cosine curve results in a substantial underestimation of blood flow velocity. θ, angle of incidence between the orientation of the ultrasound beam and that of the blood flow.

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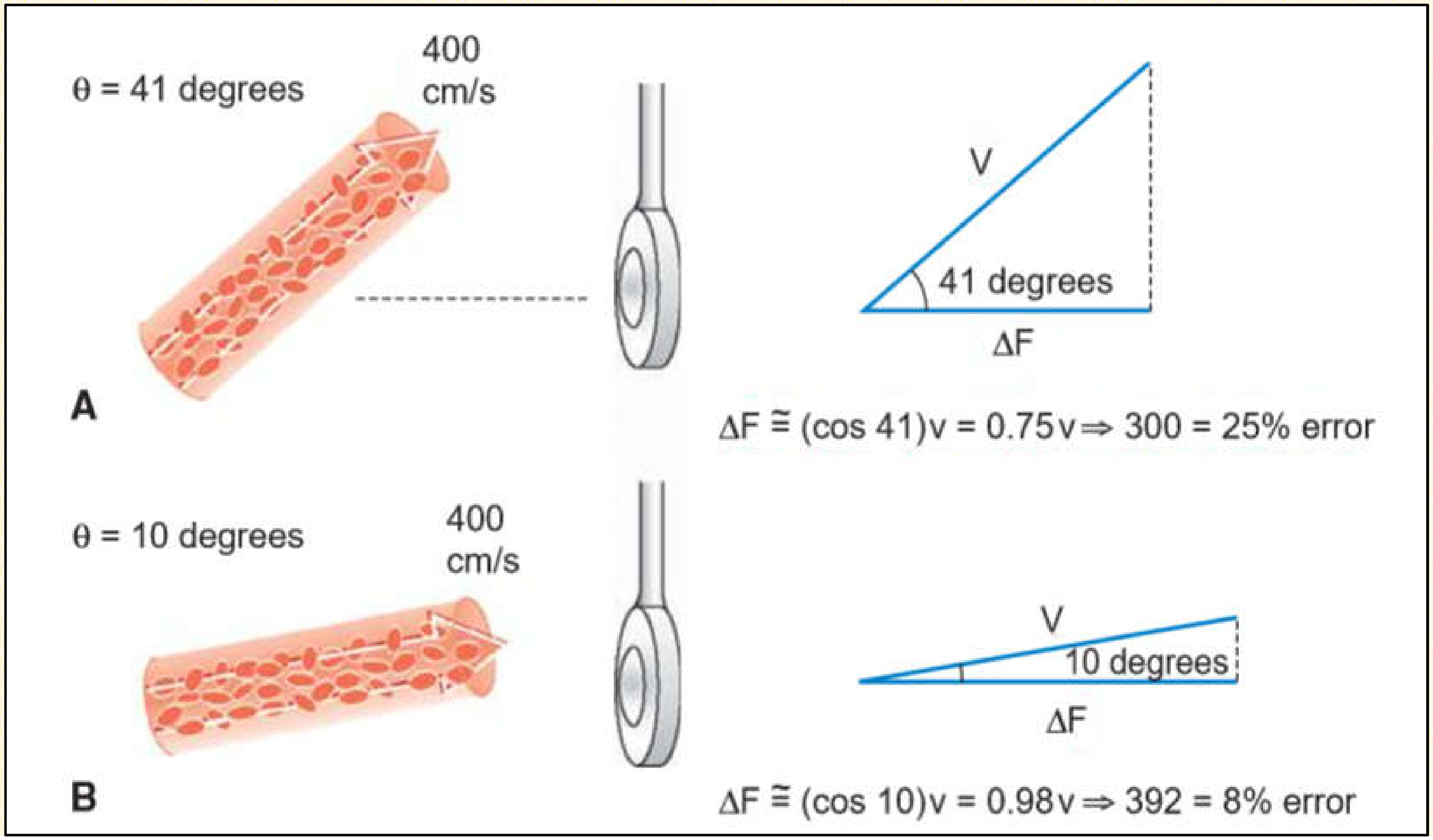
Underestimation of blood flow velocity



A: With an angle of 41 degrees, the vector component of blood flow velocity in the direction of the ultrasound beam is only 75% of the total. **B:** With an angle of 10 degrees, the vector component of blood flow velocity in the direction of the ultrasound beam is 92%, and the practice of ignoring the cos θ leads to a clinically acceptable 8% underestimation of velocity

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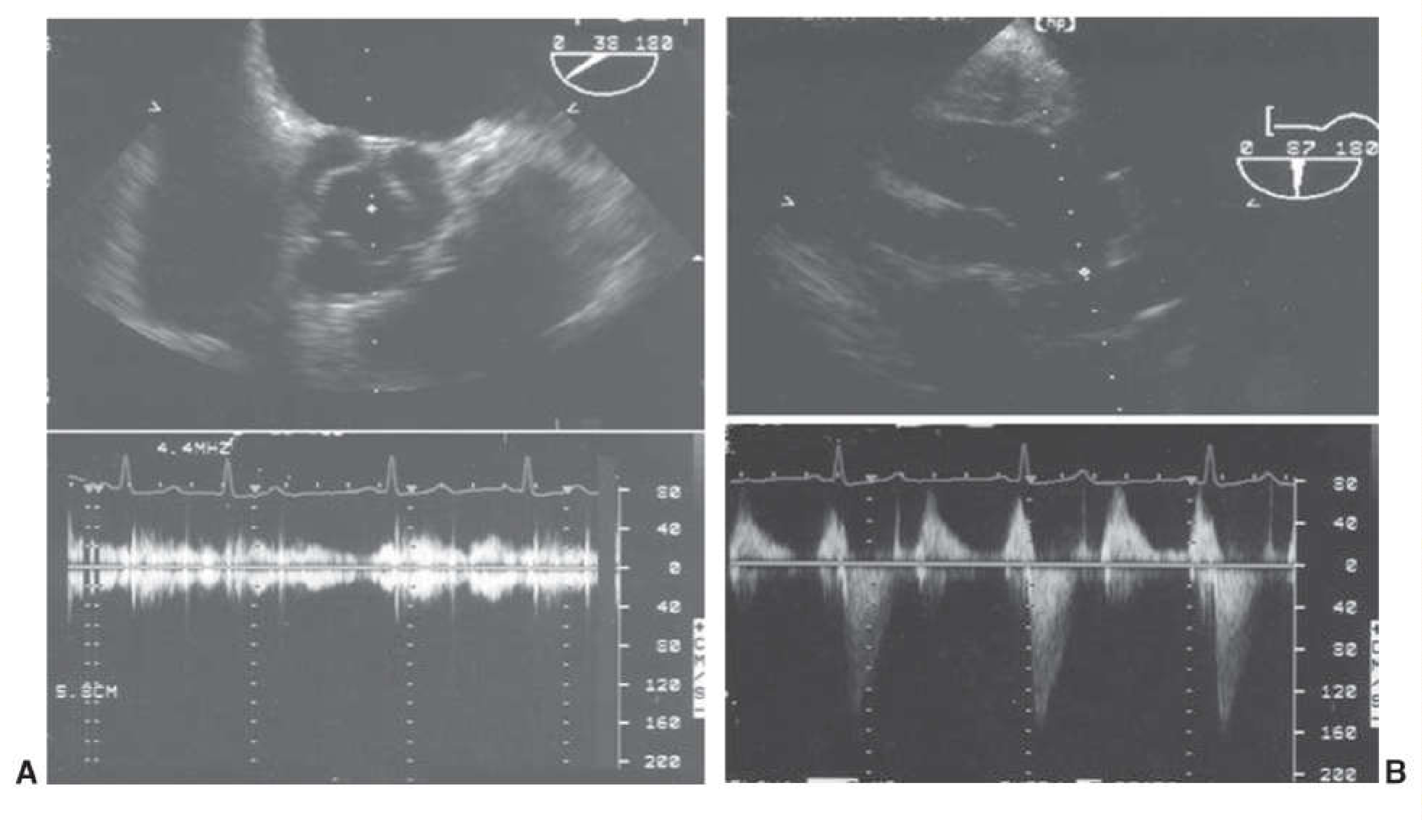
Comparison of views 2D imaging versus Doppler flow measurement



A: 2D echocardiography from the ME aortic valve short-axis view (top) provides high-fidelity images of the valve leaflets and their excursion. the continuous wave Doppler measurement of blood flow velocity (bottom) will substantially underestimate blood flow velocity. **B**: After repositioning of the probe to obtain the TG long-axis view (top), the direction of the ultrasound beam is parallel to the LVOT and ascending aorta, providing excellent continuous wave measurements of blood flow velocity (bottom).

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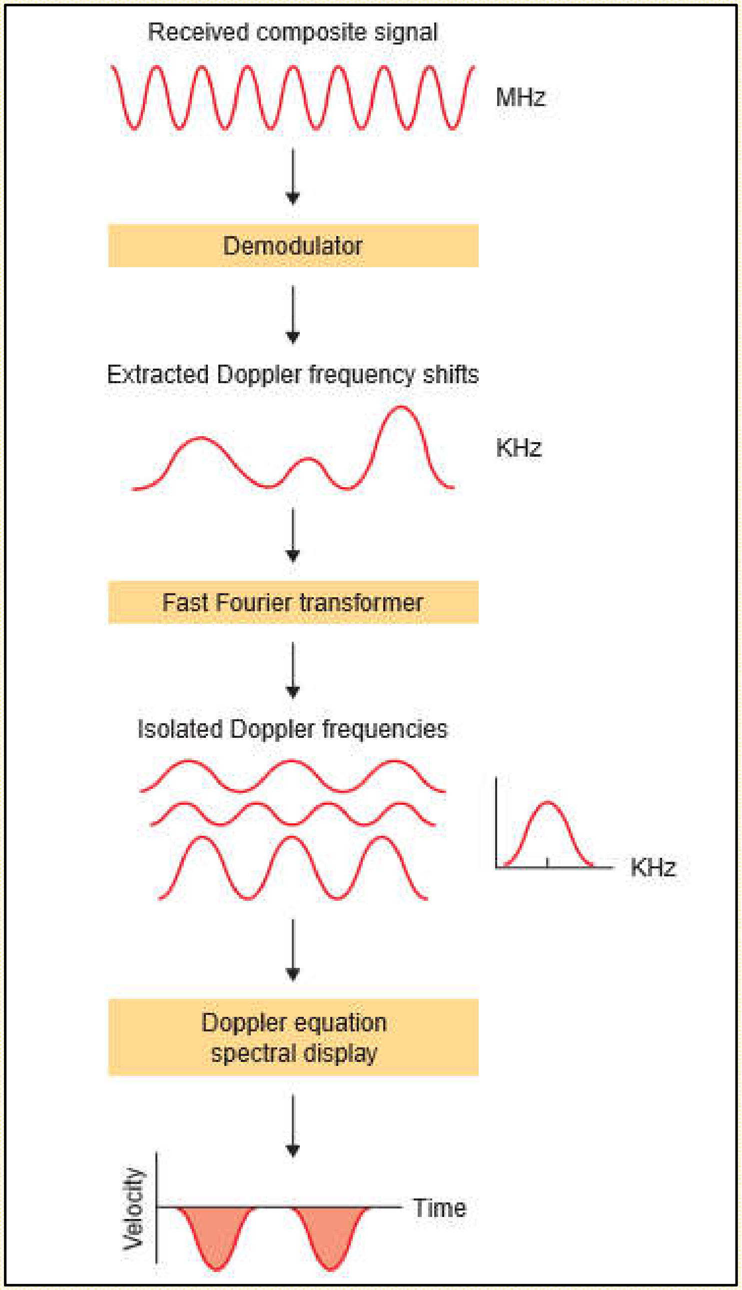
Isolating the Doppler Frequency Shift



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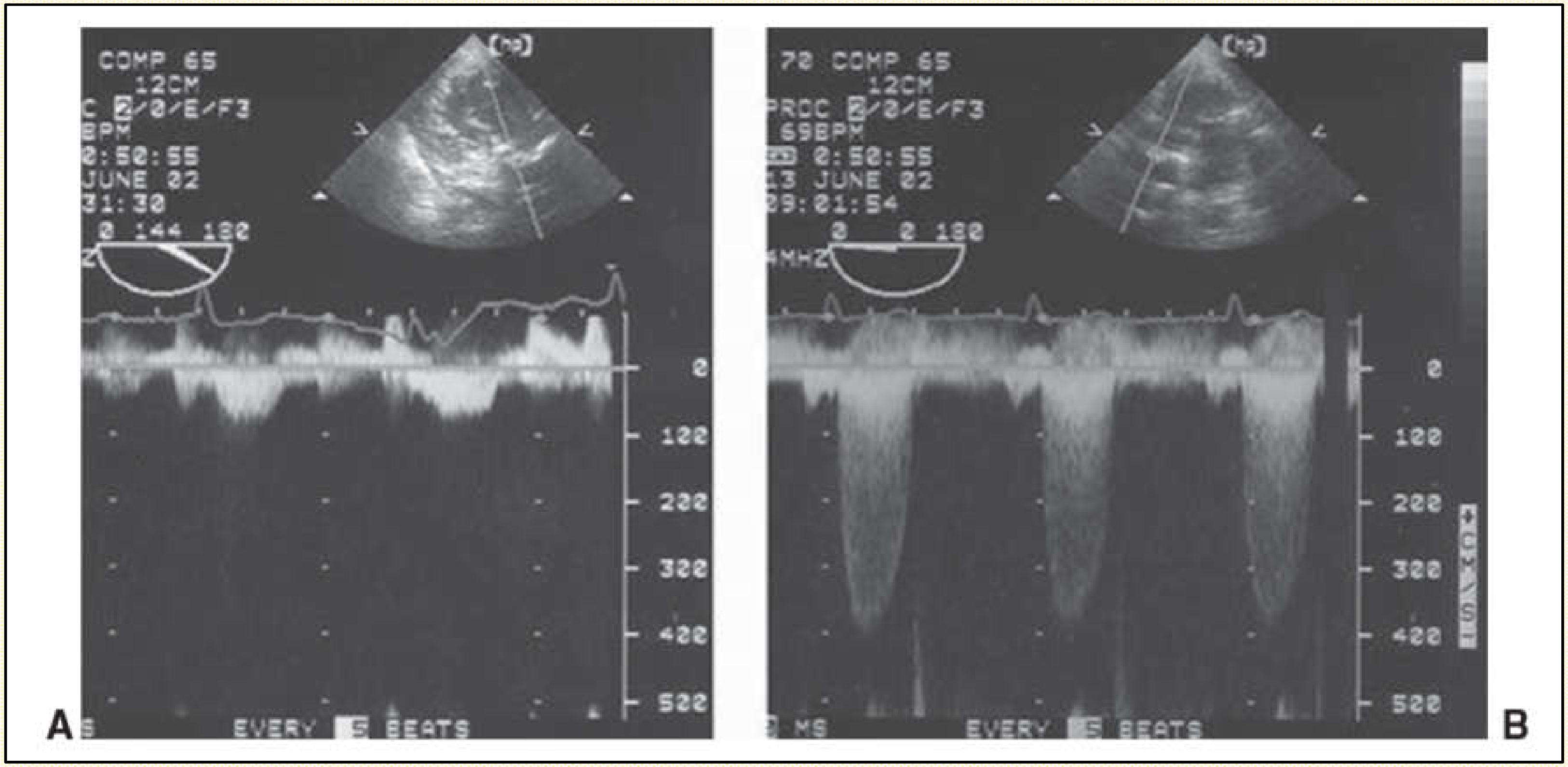
Hunting for the jet core



A: Despite high-quality 2D imaging of the TG long-axis view, Doppler interrogation of the transvalvular flow fails to detect the high-velocity flow of aortic stenosis. The wispy signal waveform provides no clear definition of peak velocities. **B:** After adjustment of the probe position to obtain the deep TG long-axis view, the resulting Doppler interrogation detects a 400-cm/s high-velocity jet, revealing aortic stenosis. Note the potential for misdiagnosis if the echocardiographer bases the diagnosis on the initial signal obtained in (A).

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Limitations of Pulsed Wave Doppler

Maximal frequency = ½ PRF = Nyquist limit

(PRF: Pulse Repetition Frequency)

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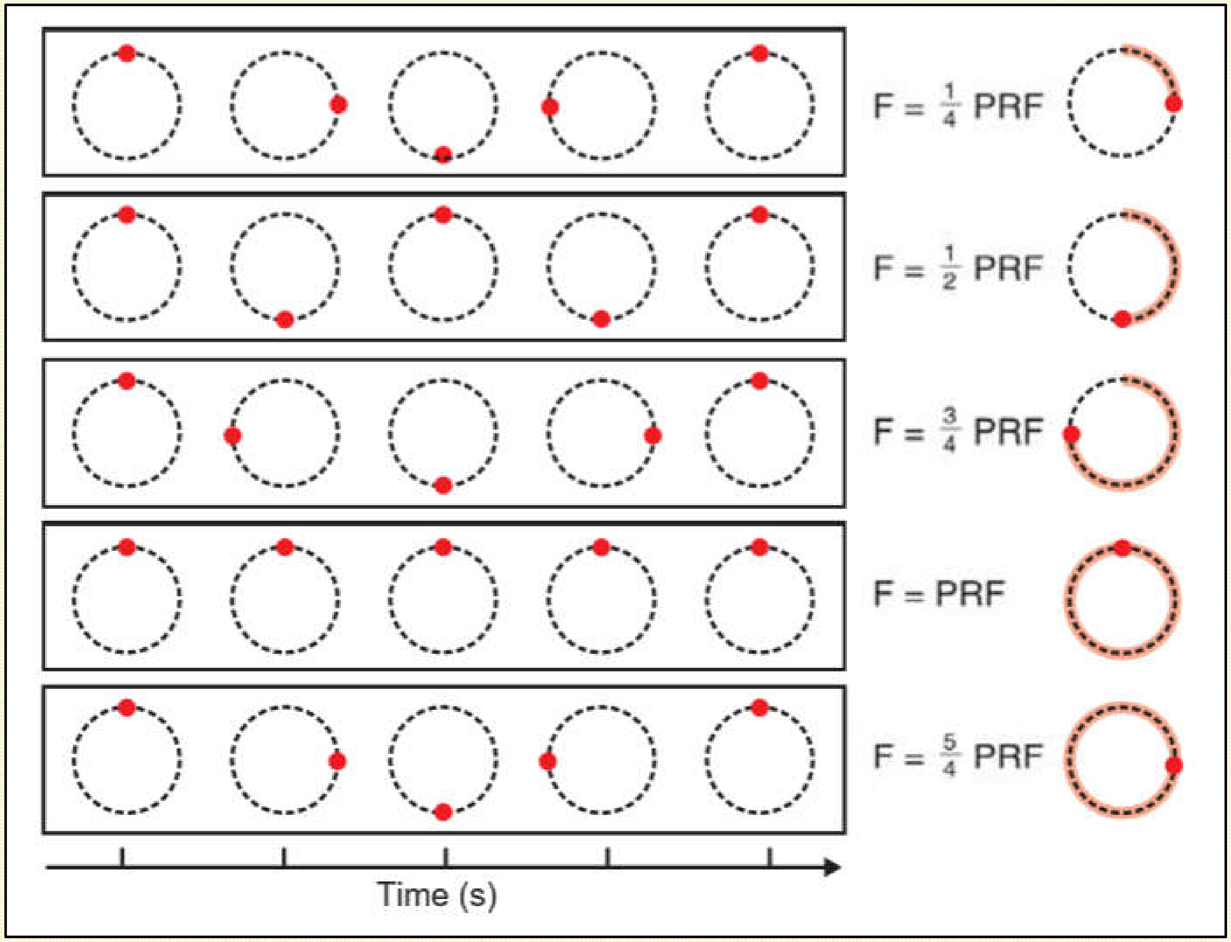
Nyquist illusions



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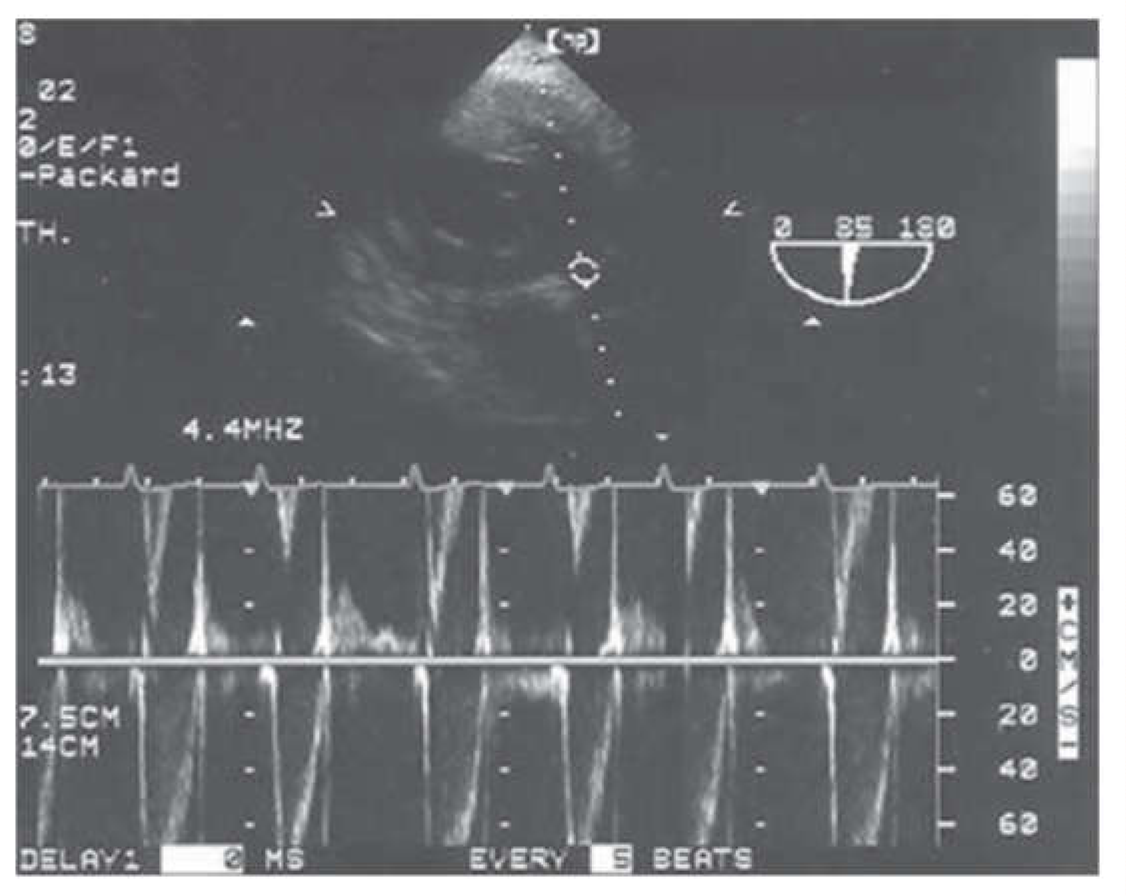
Alias artifact



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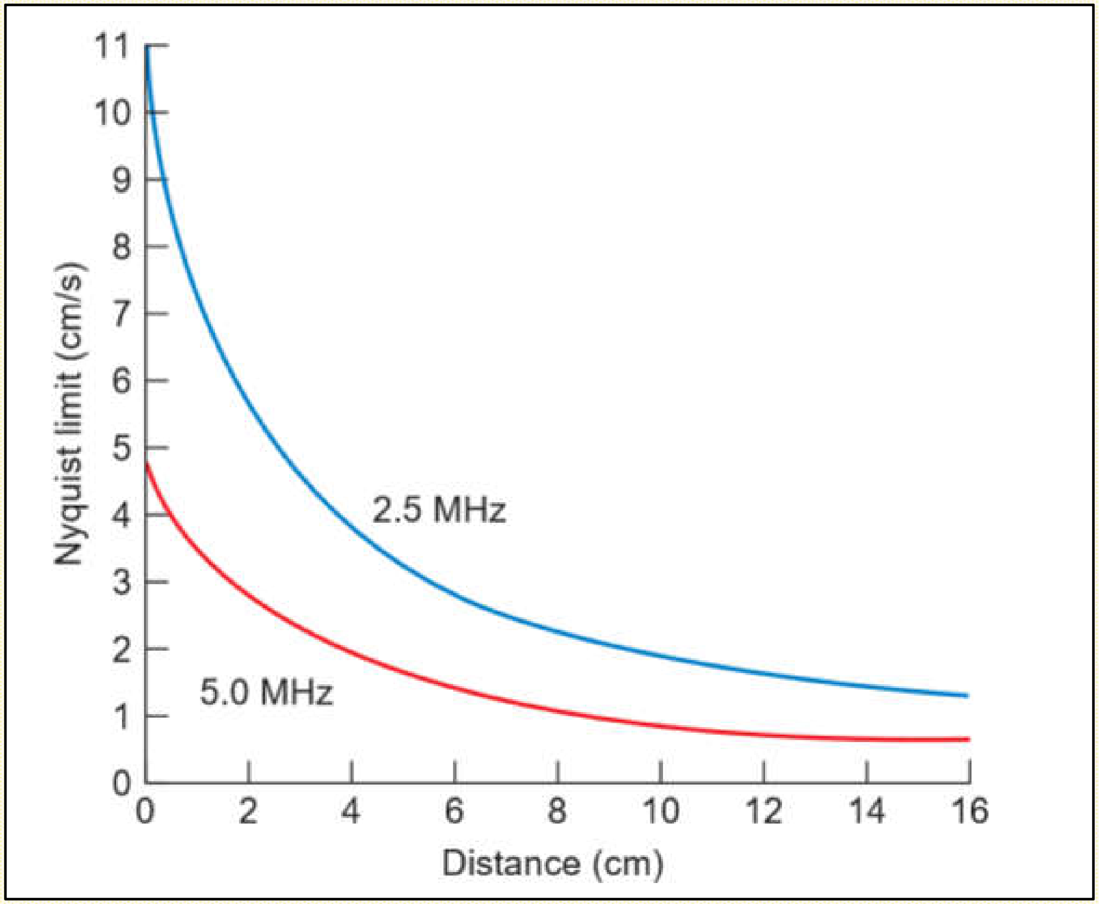
Effect of distance and frequency on the Nyquist limit



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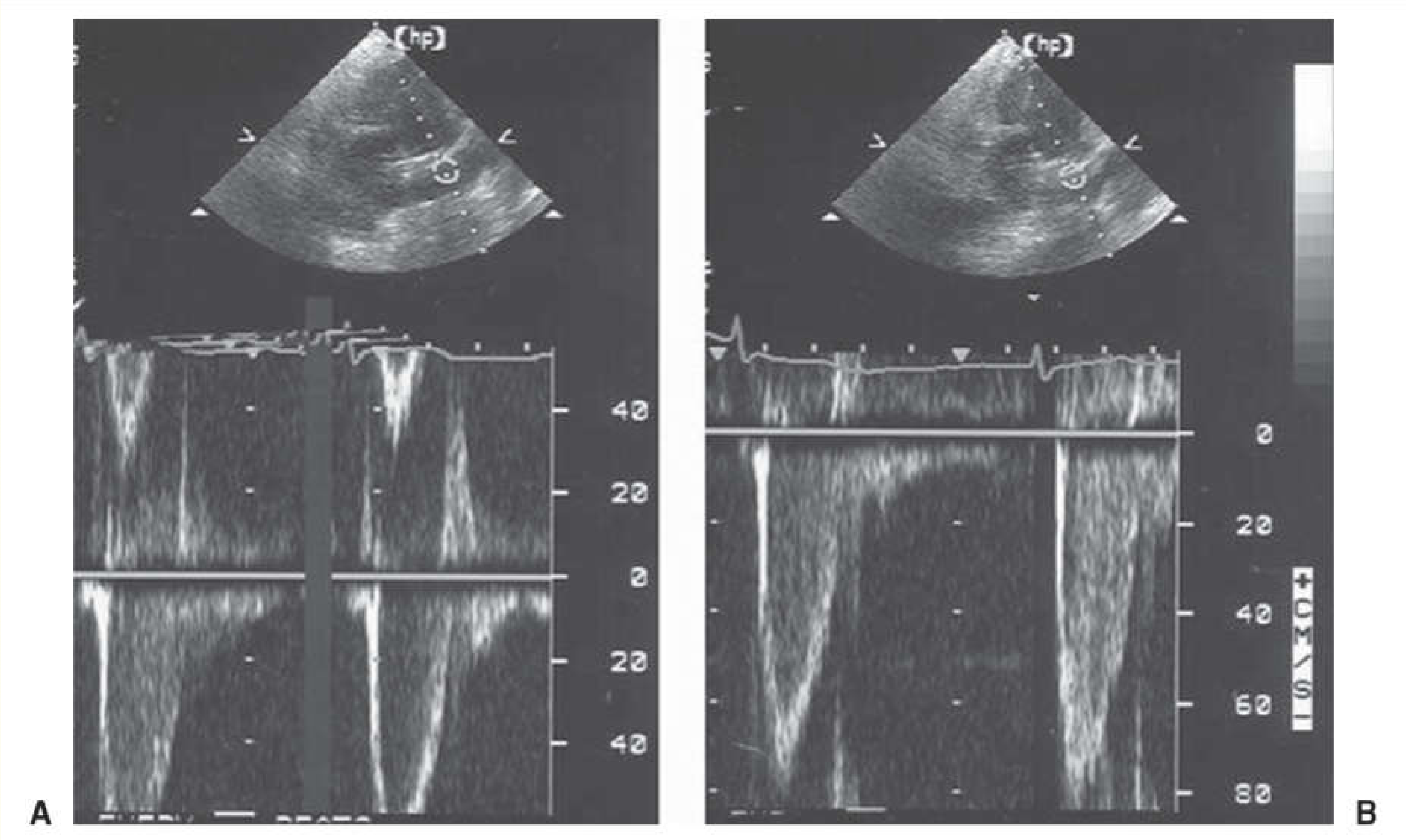
Effect of baseline setting on pulsed wave Doppler aliasing



A: With the velocity baseline set in the midportion of the display, the signal aliases at 50 cm/s. **B:** The baseline has been adjusted to the upper portion of the display, which increases the Nyquist limit to more than 80 cm/s for flow away from the transducer and captures the spectral signal without aliasing.

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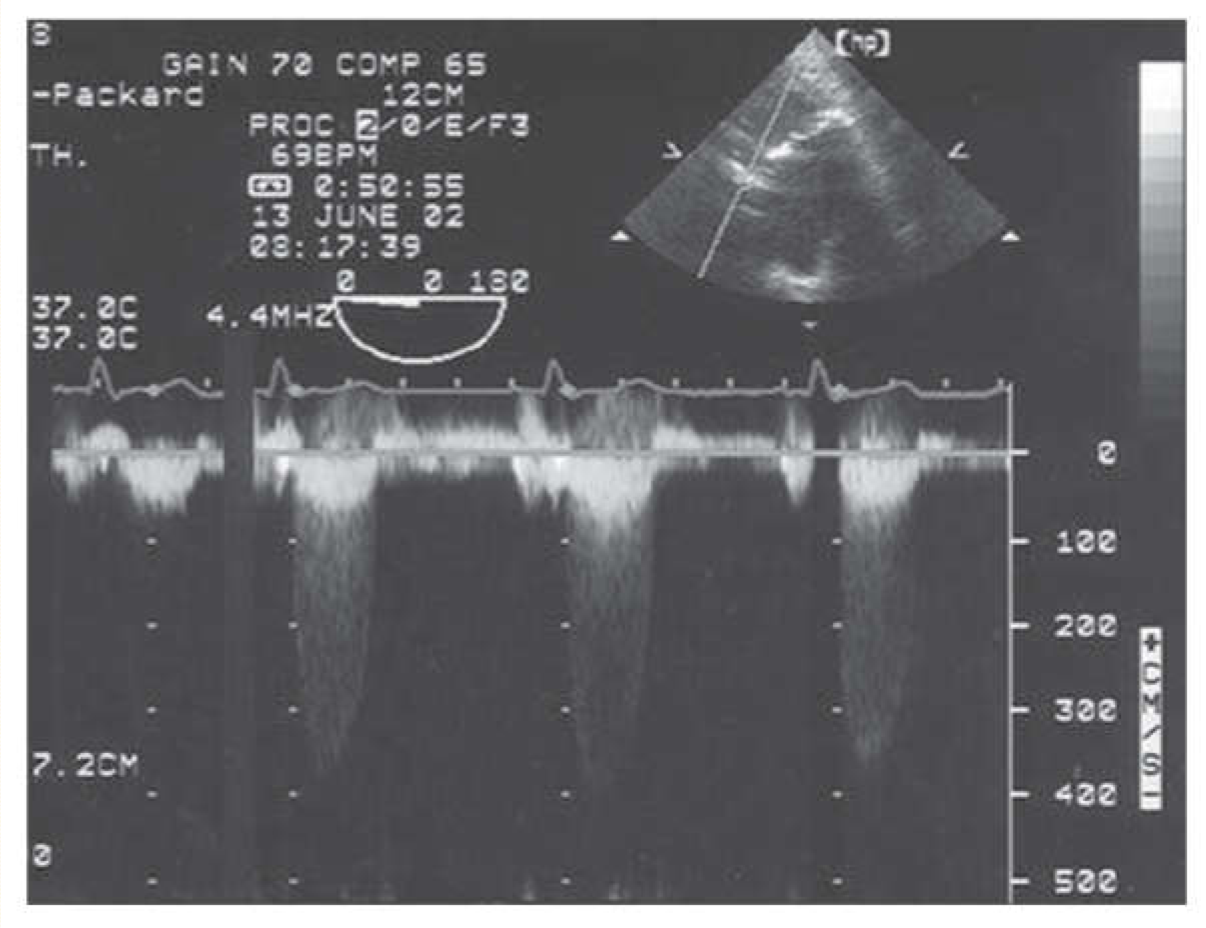
Continuous wave spectral signal



Top: In this example, the Doppler beam was positioned from the deep transgastric long-axis view.
Bottom: The resulting spectral signal shows two distinct peaks, a pattern often referred to as a double envelope.

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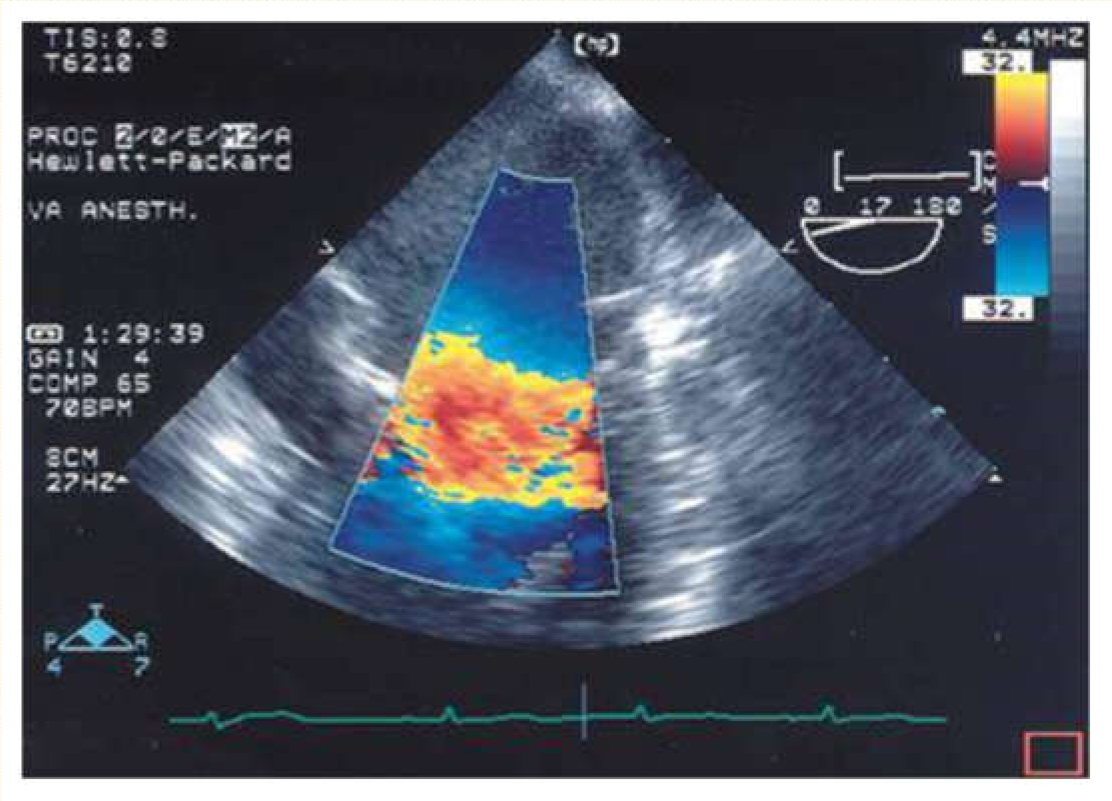
Aliasing of color display



Blood flow through the mitral valve (midesophageal four-chamber view) during early diastole results in aliasing in the color flow mapper

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