# Technical Note: Angle of Insonation in Doppler Imaging

## Background

In ultrasound imaging, the user needs to make fine adjustments to the angle of the probe, especially when wanting to measure accurate blood flow velocities in specific blood vessels. There are, of course, multiple angles that can be used. **Figure 1** illustrates two probe angles in relation to the blood flow in the abdominal aortic blood vessel. Depending on the subsequent angle chosen, the analysis of blood flow velocity can be dramatically affected.

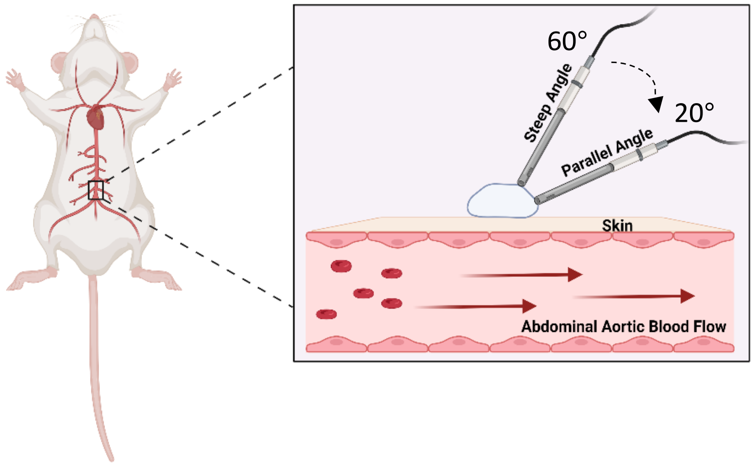


**Figure 1. Different Probe Angles in Relation to Blood Flow.** Two different angles of insonation, or the ultrasound probe angle in relation to blood flow through a vessel, are illustrated. The angle chosen will have implications for the subsequent analysis.

### Why is the angle between the probe and blood flow important?

The angle of insonation or the angle between the probe and the blood flow in a vessel, ultimately determines the accuracy of the measured blood flow velocity. Velocity is inversely related to the cosine of the angle ($\cos(\theta)$). When the probe is directly in line with the blood flow ($\theta$ = 0° or 180°), velocity measurement is at its most accurate.

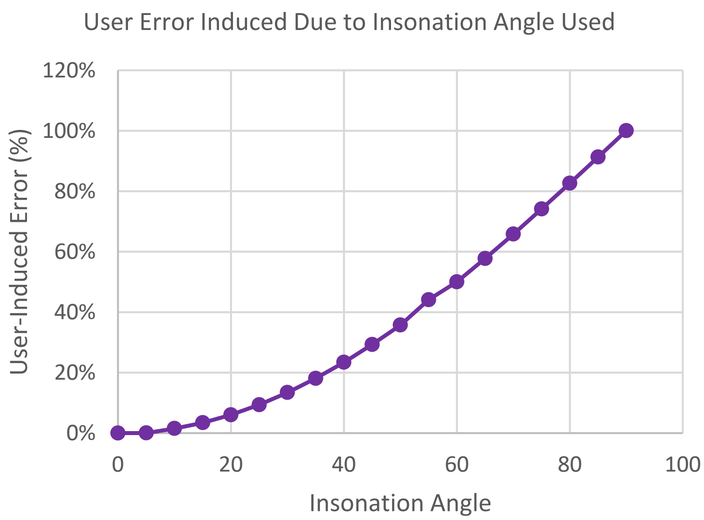


**Figure 2. Increasing User-Induced Error Due to Increasing Insonation Angle.** At the shallower angles (0 - 20°), the error introduced in the $\theta$ are minimal and lead to a velocity that has acceptable error. However, for angles higher than 60°, the error induced is dramatic and will lead to significant inaccuracies in measurement.

However, increases in the insonation angle will cause user-induced error and artificially increase the measured blood flow velocity. When the angle is below 20°, the error induced is minimal; however, at angles around 60° or higher, the measurement quickly becomes inaccurate, as shown in **Figure 2**.

**Figure 3** shows repeated imaging of the same animal minutes apart with only changing the angle, highlighting a 25% difference in measured peak blood flow velocity solely due to changing the angle of the probe. This example and others highlighted in research show the need for proper and consistent insonation angles, especially in longitudinal, serial blood flow velocity measurements[1-3]. Inconsistent incidence angles for longitudinal measurements can lead to large errors in velocity estimation, causing variability that will artificially amplify or mask differences, regardless of pathology.

### How can blood flow velocity be accurately measured using the Indus Doppler Flow Velocity System (DFVS)?

- **The compact, pencil-like design of the DFVS probes allows for easy and accurate alignment with blood flow.**

Ideally, the insonation angle would be 0° and at most 60°. However, multiple piezoelectric crystals are required in the design of typical ultrasound probes, which increases the overall size of these probes. Since most blood vessels are horizontal in anesthetized animals, we are rarely able to achieve correct insonation angles with ultrasound probes. Most ultrasound scanners are designed to account for this limitation and utilize angle correction methods

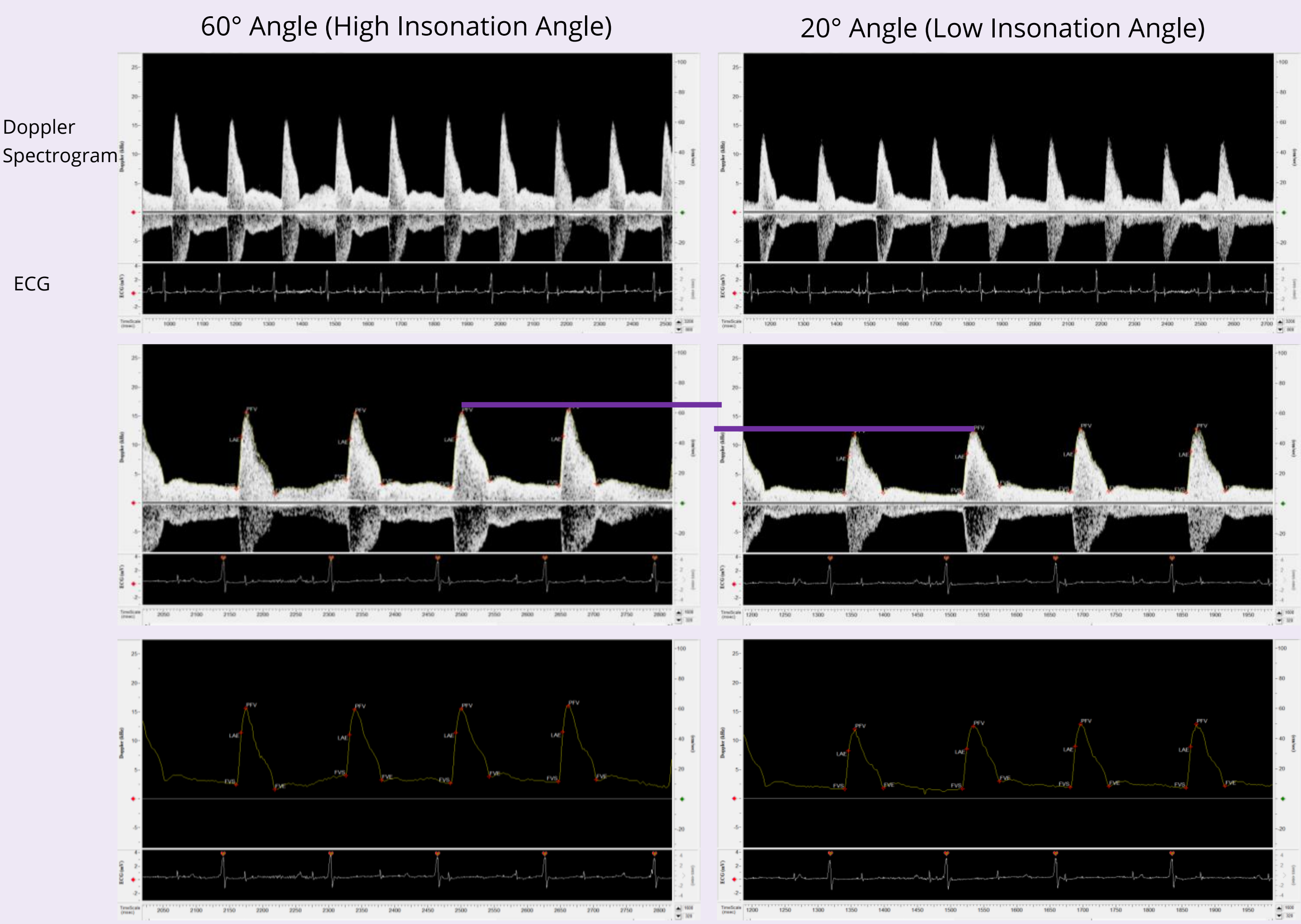


**Figure 3. Doppler Signal from Mouse Abdominal Aorta Illustrating the Importance of the Angle of Insonation.** Example abdominal aortic blood flow velocity imaging taken minutes apart from each other in the same C57B6J mouse illustrates how there is a significantly increased peak velocity when a high insonation angle of 60° (blood flow velocity of ~60 cm/sec) is chosen over a low insonation angle of 20° (~48 cm/sec). This highlights the need for a consistent probe orientation in line with blood flow (low insonation angles) to maintain the accuracy of measurements.

post-processing; however, large insonation angles have been shown to lead to gross overestimations of blood flow velocity, regardless of these correction methods. One group found that at an insonation angle of 40°, 50°, 60°, 70°, 80°, and 88° when compared to a 30° angle, there was an average 8%, 22%, 36%, 80%, 160%, and 1040% increase in velocity measurements, respectively[4].

**However, due to the unique sizing and design of the single-element DFVS probe with a diameter of around 2.5 – 3 mm, low insonation angles of 15 – 30° are easily achievable from a variety of blood vessels or cardiac chambers**. Typical user error induced due to the large size of typical ultrasound probes is minimized, allowing for accurate velocity measurements.

It should be noted that independent of insonation angle, Doppler-only users will see more accurate velocity measurements than with typical ultrasound systems due to the decreased spectral broadening that also occurs with the design of these probes[5].

## System Overview

The DFVS is a high-frequency, real-time pulsed-Doppler measurement device, as shown in **Figure 4A**, with integrated data analysis software designed to measure blood flow velocity in small animals, such as mice and rats. Both 10 MHz and 20 MHz miniature handheld probes can be utilized, with a probe shown in **Figure 4B** and an enlarged image of the probe tip shown in **Figure 4C**.

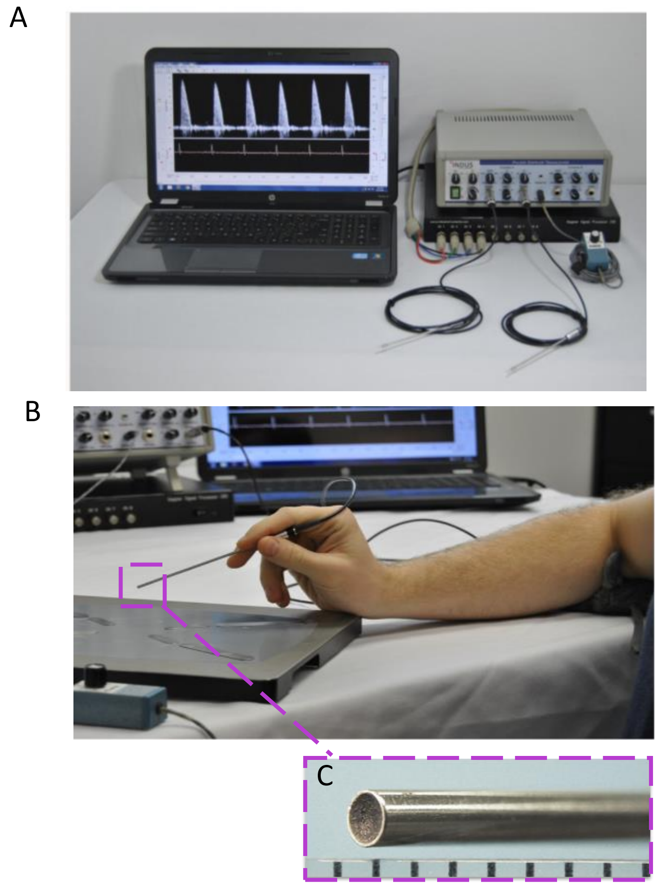


**Figure 4. Overview of System Set-Up.** A) typical Doppler Flow Velocity System set-up, B) the miniature handheld probe, and C) the magnified inset of the probe tip measuring about 2.5 – 3 mm in diameter.

*If you have any questions which equipment best meets your research needs, feel free to contact us to discuss your research. We also have many resources available, from scientist webinars to journal citations, to help point you in the right direction.*

To see the imaging systems and lab equipment that we offer, please visit our website (www.scintica.com) or feel free to reach out to us via email at info@scintica.com or by phone at 832-548-0895 and we would be glad to assist you.

## References

1. Logason, K. *et al.* The Importance of Doppler Angle of Insonation on Differentiation Between 50–69% and 70–99% Carotid Artery Stenosis. *European Journal of Vascular and Endovascular Surgery* 21, 311–313 (2001).

2. Campbell, K. A., Kupinski, A. M., Miele, F. R., Silva, P. F. & Zierler, R. E. Changes in Internal Carotid Artery Doppler Velocity Measurements With Different Angles of Insonation. *Journal of Ultrasound in Medicine* 40, 1937–1948 (2021).

3. Rizzo, R. J. *et al.* Mesenteric flow velocity variations as a function of angle of insonation. *J Vasc Surg* 11, 688–694 (1990).

4. Park, M. Y., Jung, S. E., Byun, J. Y., Kim, J. H. & Joo, G. E. Effect of beam-flow angle on velocity measurements in modern doppler ultrasound systems. *American Journal of Roentgenology* 198, 1139–1143 (2012).

5. Eicke, B. M., Kremkau, F. W., Hinson, H. & Tegeler, C. H. Peak Velocity Overestimation and Linear-Array Spectral Doppler. *Journal of Neuroimaging* 5, 115–121 (1995).