DOPPLER FLOW VELOCITY SYSTEM VS. ECHOCARDIOGRAPHY FREQUENTLY ASKED QUESTIONS

Why do I need a DFVS when I already have an Echo machine?

1. More Accurate Measurements of Pulse Wave Velocity and Peripheral Vascular blood velocity:

Pulse Wave Velocity (Aortic Stiffness): Simultaneous measurement of 2 velocity spectrograms at two different sites, (e.g. the aortic arch and abdominal aorta) can be performed, permitting the same pulse to be observed at the two sites instead of making sequential measurements on different pulses and sites. This eliminates possible variations between pulses due to factors such as inherent changes from beat to beat of the heart, or transient effects of a drug or other metabolite.

Peripheral Vascular Measurements: Smaller probes (2.5 – 3.0 mm) reduce the potential for measurement error of peak blood velocities by permitting blood velocity measurements while holding the probe at angles of less than 15°. The calculation of blood velocity involves $\cos\theta$, where θ is the angle between the sound beam and blood flow vector. As θ increases, as is required with traditional echo probes, the error introduced into the velocity measurement increases as well. In general, DFVS probes offer easy maneuverability and positioning to acquire Doppler flow velocity spectrograms.

2. Small and Portable:

Small DFVS footprint and lower cost permits multiple or portable installations of the DFVS whereas with the high cost Echo system access is often confined to core labs where scheduling may be difficult and usage costs can be high.

3. Stand Alone Assessment:

DFVS measurements in the ascending aorta to measure cardiac contractility can be less prone to error given the ability to hold the probe at low angles.

How can Cardiac Function be assessed with the DFVS?

Cardiac systolic function is assessed by measuring the blood velocity at aortic root and through aortic acceleration. Diastolic function is assessed through the measurement of mitral blood flow velocity (biphasic Early-E & Atrial-A waves) at mitral orifice and using E/A ratio to determine relaxation.

When are DFVS measurements more accurate than traditional echo?

For many vascular measurements echo probes are held at higher angles (60-90°) than DFVS probes and any small deviation from the angle used in a prior measurement can result in a significant error – a situation that can be particularly problematic in serial studies. The smaller DFVS probes are used at a shallow angle (between 0-15°), resulting in very small errors in the measurement of peak velocity as referenced below.

Why is Aortic Flow Velocity/Aortic Acceleration measured by DFVS a better measure of Cardiac Systolic Function than Fractional Shortening by Echo?

Regional variations are eliminated by the DFVS when overall contractile function of the left ventricle is measured as a system (aortic blood velocity measured at aortic root) during systolic (ejection) phase of the cardiac cycle instead of having to select a base-to-Apex location with an Echo system that can vary depending on disease conditions and the angle at which the user holds a traditional echo probe.

- Disease conditions such as in a myocardial infarction model, most often affect the apex of the heart while the rest of the heart remains functional. If measurement is made in an affected area then value is smaller; if the fractional shortening is made in an unaffected area the value may be larger; thus the measured value does not reflect the overall contractile function.

- LV Fractional Shortening is typically measured using an echo system either by M-mode (1-dimensional) or B-mode (2-dimensional), thus the value of this measure, particularly during serial studies, can be affected by the angle with which one holds the echo probe. DFVS probes are used at an angle of less than 15° where over estimation of aortic blood velocity is not possible and under estimation error is very small.

Why is the DFVS a fraction of the cost of an echo system?

1. The DFVS uses less complex probes to acquire the easily recognizable, one dimensional, wave form shapes. Echo systems require probes with expensive multi-crystal liner arrays in order to capture two and three dimensional images.

2. Operational costs are reduced as DFVS probes offer increased durability than Echo probes (e.g. not easily damaged when dropped). Training and usage costs also can be lower with the DFVS system due to tighter confidence intervals, reduced training time and reduced animal requirements.

3. DFVS probes are highly durable and lower cost to replace, if required.

How can DFVS signals be acquired from the appropriate blood vessel or valve area within the heart without an image?

- Unique waveforms and sounds result from orienting the DFVS probe so that the path of the pulsed wave aligns along the artery (examples attached). Signal depth controls are then adjusted so as to place the sample location in the artery. The coordination of visual (waveform), audio of the waveform, and orientation of probe (inclusive of muscle memory) all work together to verify the appropriate location is being measured. Anatomical knowledge facilitates finding the appropriate location for measurement.
- Signals from difficult-to-access or diseased vessels can be identified by making initial measurements in surgically exposed vessels of interest and then repeating these measurements in recovering or healed animals; individual labs may need to establish waveforms with initial invasive procedures and then use those waveforms as the standard.

How can the DFVS Doppler spectrogram be optimized when measuring blood flow?

Fine adjustments of probe orientation (site and angle) to maximize signal strength and velocity, along with adjustment of the depth of sample location, improve the shape and sound of the waveform displayed by the DFVS system.

How do we measure Cardiac output without knowing aortic diameter?

Peak aortic outflow velocity, measured at the aortic root, is used as an index of cardiac output (with the assumption that aortic diameter is not different between two groups of subjects).

Cardiac output (CO) can be estimated by calculating the area under the aortic flow velocity curve to get stroke distance (SD), multiplied by heart rate (HR), and then by an estimate of aortic cross-sectional area (CA) using the following allometric equation: **CO= SD x HR x CA**

- Aortic Radius (cm) = 0.18 x $W^{3/8}$ where W is body weight in kg (e.g. 25 g mouse = 0.025 kg)
- Aortic radius estimate of a 25 g mouse = 0.18 x $(0.025)^{3/8}$ = 0.045 cm = 0.45 mm

How does angle between the probe and blood flow effect velocity measurements?

Velocity is inversely related to $\cos\theta$. This implies that at $\theta = 0°$, velocity is at a maximum and decreases as the angle increases. The effects of $\cos\theta$ on the velocity decrease are minimal up to $\theta = 15°$. However, for angles higher than 15° the velocity decrease is dramatic.

Echo probes are often used at a large angle (e.g. 60 - 90°) and repeated measurements need to be made with as close to the same angle as possible, since even a small deviation can lead to a large error in velocity estimation. Conversely, DFVS probes are used at a shallow angle (<15°) with typical user inconsistency resulting in very small errors in velocity measurements, therefore not requiring angle correction.

The following chart clearly illustrates the effect and importance of θ:

Degrees (θ)	5	10	15	20	25	30	45	60	75
Velocity (cm/s)	57.75	58.64	59.79	61.46	63.72	66.68	81.67	115.5	223.13

Why are small angles achievable with the DFVS and not with the echo system?

- Probes used for echo systems have numerous elements required for image acquisition, thus increasing the footprint of these probes. When used on small animals these probes prevent users from achieving small angles on many of the blood vessels and valve areas in the heart, because most vessels and blood velocity vectors are horizontal in anesthetized animals.
- The probes used on the DFVS have only a single element and have an outer diameter of 2.5-3mm. These small sized probes can easily be manipulated to achieve low angles to acquire Doppler signals from a wide variety of blood vessels and heart valve areas.

Why are Pulse Wave Velocity Measurements more accurate with DFVS?

Using two probes simultaneously, DFVS is able to make simultaneous measurement of flow velocity from two sites on the aorta or other arteries to calculate pulse wave velocity to determine the stiffness (or compliance) of that segment between the two sites. Echo systems must carry out sequential measurements in the required locations.

Can DFVS also be used for Large Animals?

With the DFVS highly accurate and reproducible measurements in conscious (small & large) animals can be obtained using implanted silicon cuff transducers, with the leads tunneled subcutaneously to have them exit at the back of the neck. With the surgically implanted DFVS cuffs the measurements are made at the exact same position every time, as the probe is sutured in place. This reduces the variability due to positioning of the echo probe on a conscious animal which must be completed for every measurement.