Use Of 2D Vector Velocity And 3D Ultrasound Can Non-Invasively Measure Intravascular Pressure Changes, Gradients And Flow Abnormalities

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Conflict of interest

JB Olesen, PhD consultant for former BK Ultrasound DK

Ultrasound blood flow estimation

well-established technique to assess hemodynamic conditions

Three different modes, spectral, power, and color Doppler

- a common denominator; incapable to detect blood flow perpendicular to the direction of the emitted ultrasound beam

Doppler - Angle-Dependent flow imaging

Fails to estimate flow at 90°

\[ v = \frac{v_z}{\cos(\theta)} \]

\[ \cos(90°) = 0 \]

\[ \Delta F = 2 F_v \cos \theta / C \]

Background

Atherosclerotic vessels are a challenge to evaluate quantitatively using spectral Doppler ultrasound due to the complex flow phenomena in different vessel geometries

Vector velocity ultrasound is angle independent and provides flow information that may potentially improve diagnosis and tx

VFI vs. Doppler

90° beam to flow angle

Figures 1-3 show flow in vivo across arteries and veins. The figures are presented to show the potential of vector flow imaging (VFI) vs. spectral Doppler imaging (Doppler). In a vessel with an angle-dependent flow, axis (A), the peak flow magnitude is higher than in the case of Doppler imaging (B), due to the VFI flow information acquired with an angle-independent approach, which uses a color-coded flow with intensity of direction and magnitude. The figures are adapted with permission from BK Medical, Denmark.
Transverse Oscillation

- Angle-independent velocity estimation
- No assumptions of flow angle
- Estimation of flow at 90°
- Visualization of complex flow patterns

Hansen PW et al., New technology - demonstration of a vector velocity technique.

When disturbed flow was detected a 15 s record was made. The recording contained flow both in the lesion and proximal/distal to the lesion. Disturbed flow was defined as vortices, flow in multiple directions and/or suddenly occurring aliasing indicating increasing flow velocities.

VFI provides 2D images of the blood flow, where each pixel contains quantitative information about direction and velocity with superimposed vector arrows to facilitate flow visualization.

Vector concentration from angle-independent vector velocity estimates is a quantitative index, which is simple to calculate and can differentiate between laminar and complex flow.
Vector Flow Imaging

Measure laminar flow at any angle up to complex flow

Replace/improve measures already available by conventional Doppler ultrasound, e.g., velocity and volume flow estimation

- Less operator dependent
- No angle dependency
- New insonation windows
- More data for flow estimations

Vector Flow Imaging:
A new marker for assessing a diseased aorta

Measure laminar flow at any angle up to complex flow

Offers new parameters for flow characterization using angle independent vector velocities

- Flow complexity
- Vorticity
- Shear stress
- Pressures

Figure 3: Systolic flow obtained in long-axis view for two patients. A recording of a patient with a healthy aortic valve (A) whereas the flow from a diseased valve is shown in (B). Figure shows the same patient as in (B) after aortic valve replacement. LV, left ventricle; AR, ascending aorta. Reprinted with permission from Elsevier (Ultrasound in Medicine and Biology).

The future of vector flow imaging is in 3D

2D flow estimation can visualise the complex blood flow movement in the cardiovascular system. But knowledge regarding the out-of-plane flow component is still lacking. With 3D flow estimation, all types of complex flow can be studied independently of the examiner. Flow features such as the vortex ring formation in the ventricles of the heart, or the shear stress along the vessel walls could be detected through 3D flow (Figure 6).

Summary

- Vector flow techniques, with their many advantages over conventional Doppler techniques, are powerful alternatives for blood flow evaluation.
- Vector flow imaging can visualise complex flow, refine the classic flow parameters, and introduce new flow parameters and insonation windows.
- These factors will reduce operator dependency, improve the logistical work flow for users and the diagnostic accuracy for patients.