EFSUMB Newsletter

European Federation of Societies for Ultrasound in Medicine and Biology

New Technology

Demonstration of a Vector Velocity Technique

Abstract: With conventional Doppler ultrasound it is not possible to estimate direction and velocity of blood flow, when the angle of insonation exceeds 60–70°. Transverse oscillation is an angle independent vector velocity technique which is now implemented on a conventional ultrasound scanner. In this paper a few of the possibilities with transverse oscillation are demonstrated.

Keywords: Transverse oscillation, vector velocity, blood flow, velocity estimation, Doppler

Introduction

Velocity and direction of blood flow in vessels is most frequently measured using Doppler ultrasound. The Doppler effect is the frequency change of the sound wave that occurs when either the source of the sound wave or the reflector moves. In the case of medical ultrasound, the reflector is blood cells, primarily red blood cells flowing through the vessel. With the simplest form of Doppler ultrasound (colour flow mapping) it is possible to determine the overall direction of the blood flow through the vessel, and an estimate of the blood flow velocity in the direction of the emitted ultrasound wave, i.e. the axial direction is found. It is therefore only a qualitative technique to visualize flow. By supplementing with Spectral Doppler it is possible to perform angle correction, and achieve a quantitative estimate of the velocity of the blood flow in the presumed correct direction, i.e. along the blood vessel.

One of the limitations of the Doppler technique is the drop in frame rate that occurs when scanning in du- and triplex mode (combining B-mode, Doppler and Spectral Doppler). A low frame rate makes it impossible to visualize rapid changes in the blood flow. Another limitation is the angle dependency and need for manual angle correction. Combining the Doppler equation with the Cosine function which is used for angle correction, the true velocity $v_t$, i.e. along the vessel, is given by

$$v = \frac{v_r c}{\cos \theta} = \frac{f_d c}{2f_r \cos \theta}$$

where $v_r$ is the axial velocity, $f_d$ is the received frequency, $c$ is the velocity of ultrasound in human tissue, $f_r$ is the frequency of the emitted ultrasound wave and $\theta$ is the angle between the ultrasound wave and the direction of the blood flow. From this equation it can be seen that at 90° insonation, the Doppler function is not applicable since $\cos 90 = 0$. Additionally $\cos \theta$ drops excessively steep as the angle of insonation exceeds 60–70°, and it is therefore essential to keep the angle below 60–70° to achieve a valid estimate of the velocity [1]. The angle correction can be done manually by tilting the transducer or electronically by adjusting the direction of the ultrasound wave, but either way the operator has to perform the correction based on the B-mode image. This correction procedure is difficult to apply to blood vessels with complex geometry (branching, curving, stenoses, dilatations, etc) and furthermore the velocity estimation is based on the assumption that the flow is laminar. The complex geometry and passage of e.g. valves creates complex flow profiles [2], which are not possible to visualize with Spectral Doppler, and generates misleading velocity estimations. In these vessels with complex flow arteriosclerosis is predicted, and as much information as possible is wanted [3-5].

The angle dependency have been tried circumvented in several ways, e.g. using two ultrasound beams [6], speckle tracking [7], plane wave excitation [8, 9] and transverse oscillation [10]. The latter is demonstrated in this paper.

Examples

The scans in this short report were performed on three voluntary, healthy, male subjects at age 33, 34 and 37 by an experienced radiologist. Scan sequences of the common carotid artery, jugular vein, carotid bulb, femoral vein, femoral artery and the abdominal aorta have been acquired. The study is approved by The Danish National Committee on Biomedical Research Ethics.

With transverse oscillation the conventional Doppler method is used to estimate the axial velocity component $v_x$. By manipulating the receive apodization the transverse velocity component $v_z$ is found simultaneously and the true velocity and direction of the blood flow is calculated as a vector.

Transverse oscillation is proposed by Jensen and Munk [10] and has been tested in computer simulations and with phantoms by Jensen and Udesen [11,12]. Udesen et al. have tested the technique in-vivo [13] and Hansen et al. have done in-vivo validation of transverse oscillation against MRI angiography with a high correlation between the modalities (R 0.91) [14]. Both of the in-vivo studies were conducted with the experimental scanner RASMUS at The Technical University of Denmark, Center for Fast Ultrasound Imaging.

Transverse oscillation is now implemented in a conventional ultrasound scanner (Pro Focus 2202 UltraView, BK Medical), which is equipped with a conventional Linear Array Transducer (8670, BK Medical). UltraView displays the velocity and direction of the blood flow with coloured pixels, very similar to colour flow mapping.
this is supplemented with multiple arrows of adjustable size which is superimposed real-time on the colour flow map. These arrows illustrate momentary changes in blood flow direction and velocity throughout the colour flow mapped area of the blood vessel. It is thus possible to demonstrate different flow phenomena which have never before been shown real-time on a conventional ultrasound scanner.

The sonograms presented in Figs. 1–6 were chosen from the recorded ultrasound sequences. The figures are screen shots and there has been no offline processing. Please note the angle of insonation.

Discussion

Using UltraView it is now possible to perform a real-time angle independent visualization of blood flow direction and estimation of velocity. Furthermore the velocity estimation is made operator independent, now the need for angle correction is gone. In previous studies of Spectral velocity estimation it has been shown that e.g. the manual angle correction is a cause of erroneous velocity estimation. Hoskins found 10–100% error of the estimation at maximum velocity assuming all flow is laminar [18]. Since this is not the case, cf secondary flow, the use of Spectral technique for velocity estimation is further compromised.

As previously mentioned, transverse oscillation has been validated against MRI angiography, but even this modality has limited accuracy when estimating velocity. Furthermore the estimate is generated as an average of several heartbeats, which conceals any irregularities of the individual heartbeat [16, 19]. With UltraView it is not possible to estimate the secondary flow when scanning on the longitudinal axis of a vessel, since it is only a 2D scanning, but at Technical University of Denmark, Center for Fast Ultrasound Imaging a 3D vector flow technique is being developed and implemented on the experimental scanner SARUS [20].

Conclusion

The implementation of transverse oscillation on a conventional ultrasound scanner makes it possible to scan patients and obtain angle independent estimations of blood flow velocity. At the same time it is
Injecting into a place where it will not be missed for a long time.

References


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Case of the month

The web statistics show a lot of hits on the Case of the Month coming from outside the English speaking countries. Following a recent meeting in the Publications Committee we decided to try to provide translations for some of the most recent Cases of the Month. In the coming six months we will monitor the hits on the translated pages.

Translation to other languages is also under consideration. If you wish to contribute by translating into your own language please contact the Case of the Month administrator Dr. Paul Sidhu at Paul.Sidhu@efsumb.org.

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