Basic Principles of Doppler ultrasonography

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Authors: S. Mrdjen; Novi Sad/RS
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Learning objectives

The aim is to introduce young radiologists and radiology residents with physical principles of Doppler devices for achieving the best results in this diagnosis.
**Background**

Color Doppler ultrasonography has brought a revolution in diagnosis, treatment and monitoring of diseases of the blood vessels. Although in the last decade have developed other diagnostic methods (CT angiography and MR angiography) color Doppler ultrasonography because of its accessibility, noninvasiveness, safety and easy for patient has become the method of choice in the diagnosis of vascular disease.

With this work we tried to explain in a simple way adjustment for Doppler ultrasound examination, and also to explain the basic physical principles of Doppler effect.

Japanese scientist Satomura in 1956 observed that erythrocytes can reflect ultrasonic waves and this effect is called the Doppler effect.

Doppler effect is a change in frequency of the reflected ultrasound waves backscattered from the structure that is in motion.

\[ f = (2 \cdot f_0 \cdot \frac{v}{c}) \cdot \cos \theta \] (fig 1).

- \( C \): speed of ultrasound in soft tissues
- \( V \): speed of erythrocytes
- \( f_0 \): emitted frequency
- \( f_1 \): the frequency of the reflected ultrasound

\[ f = f_0 - f_1 \]

There are two types of technical mode of Doppler imaging in medicine.

**CW continuous wave** - uses two transducers, one transmitting and the other receiving the reflected waves.

**PW pulsed wave** - one transducer is used as a transmitter and as a receiver.

Pulsed Wave Doppler has found its wide application in Doppler diagnosis.

Doppler findings are quantified by spectral frequency analysis (fig 2).

Shape of the curve depends on the contractility of the heart, blood vessel wall elasticity, blood viscosity, blood vessel diameter, distance from the heart and mostly of the peripheral vascular resistance. (fig 2)

- Laminar flow of blood: when the wall of a blood vessel is smooth and large enough, the speed is greatest in the middle of the profile (parabolic flow)
- Turbulent flow: generated if an obstacle in the blood vessel exists, there is a deviation from the parabolic flow.
The flow in the blood vessel can be displayed in two dimensions, such display is called color doppler (fig 3). The red color shows blood flowing to transducer, blue color shows blood flowing away from transducer. Triplex doppler provides the ability to view real-time images that may not be frozen.

Color Doppler is usually combined with pulse Doppler. SAMPLE VOLUME is set to place of blood vessel in which we are interested, and we get the spectrum, the morphology of organs and blood vessel flow that is encoded in color (Duplex Doppler)( fig 4)

A special form of two-dimensional view is Power Doppler F(PD) (fig 5)

For the examination of the peripheral arteries and veins linear transducer with the frequencies of 7-15 MHz is used (fig 6).

It is necessary to know all the options and buttons on the device in order to do the Doppler examination in an optimal way (fig 8).

**Setting the B-mode**

1st: Optimizing gain
2nd: Frequency (the higher frequency, higher resolution, the less penetration, and reverse ).
3rd Selection of preset
4th Setting the focus to be on the level of the object which is being observed (fig 9,10).

After B-mode involves the collor or power Doppler , and only after that pulsed Doppler (fig. 11).

You should always set up basic parameters:
1.PRF
2.Dopller gain
3.Wall filter
4.The angle between the transducer and the vessel (Doppler angle)
5.Sample volume
6.Baseline
7.Sweep speed (number of spectra are displayed graphically simultaneously).

Setting the Doppler line and angle of line is necessary for adequate measurement. Doppler line is set at angle less than 60 degrees to the vector of the vessel, and the angle of the line must be placed parallel to the wall of the blood vessel (fig. 12).

Inadequate position of the Doppler line at an angle of 90 ° measurements were misrepresented (fig. 13).
Sample volume (fig.4) marks the point at which the flow rate is determined. Sample volume should be 1/3 diameter of the artery. For very small blood vessels and veins expanding sample volume is used. Too wide sample volume in the arteries causing spectral expansion (fig. 14).

PRF scale (repeated pulsing frequency) is the number of pulses per unit of time that is transmitted to the blood vessel.(fig 15 ).
High PRF detect high-speed
The low PRF detect slow flow, and if it detects high flows occur aliasing fig (16).

Baseline indicates start and speed in the spectrum of zero ( fig 15).
Flow directed towards the transducer is above and the flow below the baseline is away from transducer. If the line moves too high aliasing occurs.(fig 17).

Adjusting color gain and color PRF ( fig 18,19,20,21 )

Doppler artifacts
1 st aliasing : Systolic peak of the spectrum was transferred below the baseline.
2 nd Image in the mirror.
3 rd Incorrectly placed WALL FILTER
4 th Incorrectly placed sample volume
5 th Electromagnetic Interference

Different tissues have different vascular resistance. For example, the brain has a low vascular resistance because it requires a large amount of blood throughout the day. Unlike muscles during activities require large amounts of blood, less in rest and the resistance in the rest is higher.

We distinguish between two types of spectrum
1.high resistance( fig 22).
2. low resistance ( fig 23).
Images for this section:

**Fig. 1:** equation to calculate the speed of blood in the blood vessels

Fig. 2: spectral frequency analysis

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Fig. 3: Color Doppler of hepatic vein

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Fig. 4: DUPLEX DOPPLER

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Fig. 5: Power Doppler

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Fig. 7: options and buttons on the device

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Fig. 8: Aorta B mode
Fig. 9: Setting the B-mode

- Selection of the appropriate preset
- Adjust the frequency of transducer
- Focus

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**Fig. 10:** Set up pulse doppler

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**Fig. 11:** Doppler line and angle of line

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Fig. 12: Inadequate position of the Doppler line at an angle of 90 °

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Fig. 13: Too wide sample volume

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Fig. 14: PRF scale and baseline

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Fig. 15: PRF low-aliasing

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Fig. 16: Baseline aliasing.

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Fig. 17: Adjusting color gain and color PRF

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Fig. 18: color gain is set too much

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Fig. 19: color gain adjusted correctly

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Fig. 20: color gain adjusted too low

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Fig. 21: high resistence spectrum

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Fig. 22: low resistance spectrum

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Imaging findings OR Procedure details

Doppler ultrasonography found application in the diagnosis of disease: peripheral artery, peripheral vein, carotid artery, vertebral artery, examination of blood vessels of the liver, kidney and other organ systems. To perform an ultrasound examination of blood vessels require a good knowledge of the physical principles of ultrasound and Doppler effect, a good knowledge of the device which performs review, and above all a good experience and education.

Images that are use in this presentation are made with ultrasound equipment GE Logiq 7 with high frequency high resolution transducer (12-14 MHz). fig 1
Fig. 23

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Conclusion

Due to the increasing number of high resolution ultrasound devices with the ability of Doppler examination a growing number of doctors with different specialties perform Doppler examinations, which are often not sufficiently reliable. For these reasons, the radiologist must take the main place in Doppler examination.
References

Personal Information

Srdjan Mrdjen, Dom zdravlja Novi Sad.

21 000 Novi Sad, Serbia.

e-mail: srdjannet@yahoo.com