Eur J Echocardiography (2002) **3,** 240–244
doi:10.1053/euje.2002.0150, available online at http://www.idealibrary.com on IDEAL®

TECHNICAL NOTE

The Difference Between Colour Doppler Velocity Imaging and Power Doppler Imaging

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The Doppler effect, which occurs on the reflection of ultrasound from moving blood or tissue, is observed as a shift in frequency of the reflected ultrasound from that of the incident ultrasound. This Doppler shift has been widely used in clinical practice as a means of measuring blood velocity[1]. Two types of Doppler Imaging are often discussed as facilities on ultrasonic scanners, namely Colour Doppler Velocity Imaging and Power Doppler Imaging. In this article the difference between the two will be described and it will be noted that, although both are used in vascular disease, Power Doppler Imaging is not extensively used at present in cardiology. A number of other names are used for these Doppler techniques, for example 'Normal Doppler' for Colour Doppler Velocity Imaging and 'Energy Doppler' for Power Doppler. The echocardiographer is obliged to ascertain what exactly each name stands for.

Simple Doppler devices that provide velocity information when their beam is directed at a blood vessel have been available for many years. Indeed images can be produced by these devices if a narrow ultrasound beam is slowly moved across a blood vessel and the blood velocity at each position displayed on a screen. However real-time Doppler imaging only became available when a breakthrough was made in fast signal processing[2]. By 'real-time imaging' we mean the production of several images per second of the scanned region. The fast signal processing rapidly produces values of the mean blood velocity at neighbouring points along the ultrasound beam and allows the beam to be swept quickly to generate a cross-sectional image of regions of blood flow. Static or slow moving tissue does not produce significant Doppler shifts in the reflected ultrasound and is therefore not presented in a Doppler image. Of course a grey shade B-mode image of these tissues is usually combined with the Doppler image. With early instruments, 15 Doppler images per second were typical but now the rate can be in excess of 50 per second.

Principle of Measurement from Echo Signals

To understand the two Doppler techniques let us revisit how echoes are produced from tissues within the body and the information these echoes carry. When a short pulse of transmitted ultrasound is scattered from a small sample volume of moving blood and an echo signal from that volume is detected by a transducer (Fig. 1), two pieces of information are obtained (Fig. 2).

1. A very accurate measurement of the time taken for the echo to return to the transducer.
2. The amplitude (size) of the echo signal i.e. the size of the pressure fluctuations in the echo.

Consider all the blood cells in the sample volume to be moving at the same speed with respect to the transducer and that a series of ultrasound pulses are transmitted at equal time intervals. Due to the changing position of the blood cells, small changes in the time taken for the echoes to return to the transducer can be detected and electronically processed to produce a signal containing Doppler effect information. The frequency of this signal is the Doppler shift in the ultrasound frequency and from it the velocity of blood is calculated by the machine. The direction of flow, toward or away from the transducer, can also be determined.

The power of the echoes (derived from the amplitude of the echoes) determines the power of the Doppler signal, both of which are related to the number of blood cells in the sample volume. Power is therefore a readily obtained measure of the number of moving cells in the sample volume.

From the above we can see that we have the means to obtain the velocity and a measure of the number of cells moving with that velocity. The latter is not a particularly accurate measurement since the power of the echo signals is greatly influenced by effects such as attenuation of the ultrasound in tissue. However, it can be used successfully to indicate that flow is occurring at

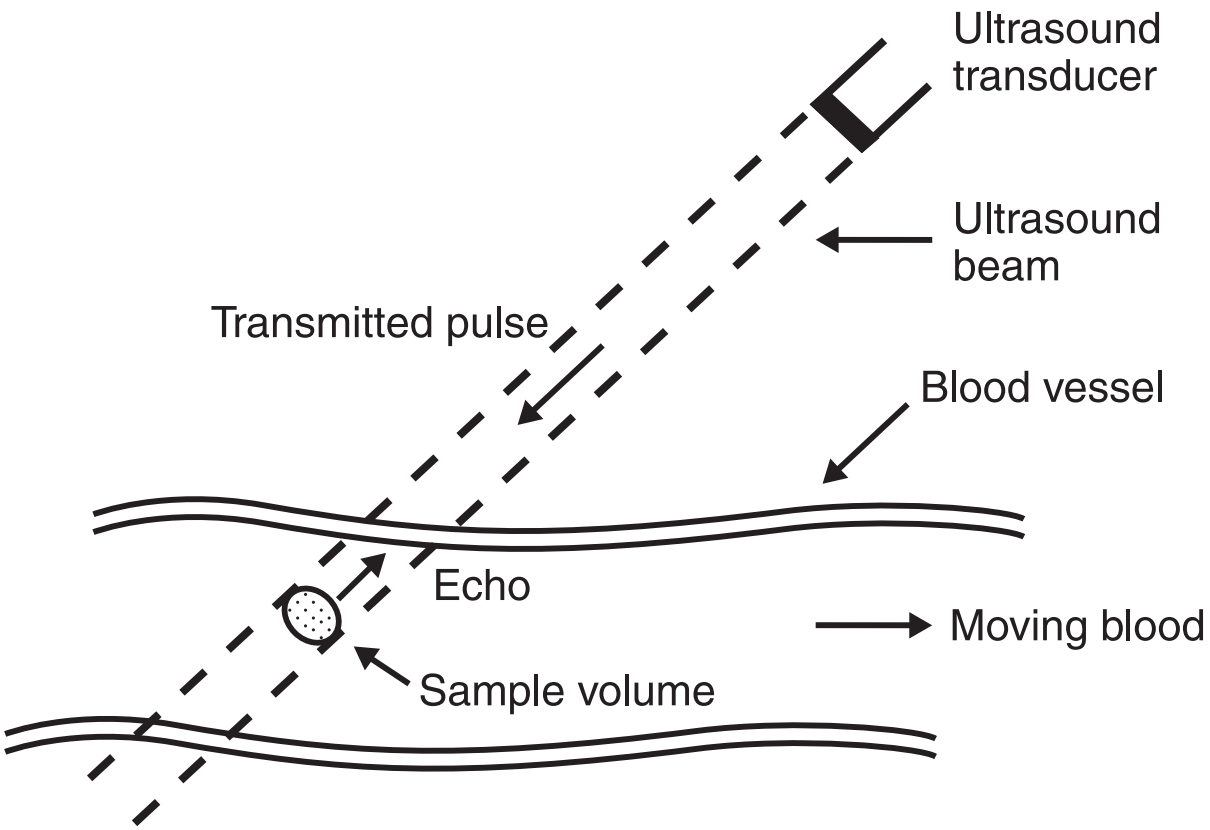

Figure 1. The production of an echo signal when an ultrasonic pulse is transmitted toward a sample volume of blood.

the location of a sample volume. Also the effects on the echoes are likely to be similar for neighbouring sample volumes so their power signals can be compared.

If a sample volume is small it is usual to assume that the velocities of the blood cells in it are all the same, whereas for a large sample volume a number of velocities may be present and hence there is a spectrum of velocities. Since the number of blood cells is the same in sample volumes of equal size, the power of the signal from each sample volume is also the same. Two factors can alter this situation, inclusion in the sample volume of some static tissue such as vessel wall reduces the power of the Doppler signal and turbulence increases it, as seen in jet flow.

Doppler Imaging

In Doppler Imaging, echoes are collected from an area of tissue through which the narrow ultrasound beam is swept. For each beam direction a pulse is transmitted and a train of echoes is collected from consecutive sample volumes located along the beam axis. With a typical commercial machine, there will be 128 volumes along the beam. The process is repeated about 10 times to obtain 10 echoes from each sample volume. Note the process of collecting 10 echoes from each sample volume can be completed in perhaps 2 ms so the process is very fast. The very small differences in the return times of the echoes from each sample volume are used to derive the Doppler shift signal for each sample volume. In such imaging the number of transmitted pulses in each beam direction is limited, since it is necessary for the beam to be swept across the scan plane as quickly as possible.

Fast signal processing of the Doppler signal from each sample volume rapidly calculates the mean velocity of the blood cells and the power of the signal. It is therefore possible to produce two images namely the Colour Doppler Velocity Image and the Power Doppler Image (Fig. 3). The direction of flow information extracted by the electronics from the sequence of returning echoes is included in the velocity images, normally shades of red denote flow toward the transducer and blue away from the transducer.

In Velocity Doppler images, it is worth noting that the velocity depicted is usually not the actual velocity, but the component of that velocity along the beam direction (Fig. 4). The values of the velocity components, presented as different colours in image pixels, are therefore dependent on the angle between the true velocity direction and the beam direction at each sample volume. This angle is often not known, so care has to be taken in interpreting images since a considerable alteration in colour can result from a change in angle rather than a change in velocity. Another common artefact is known

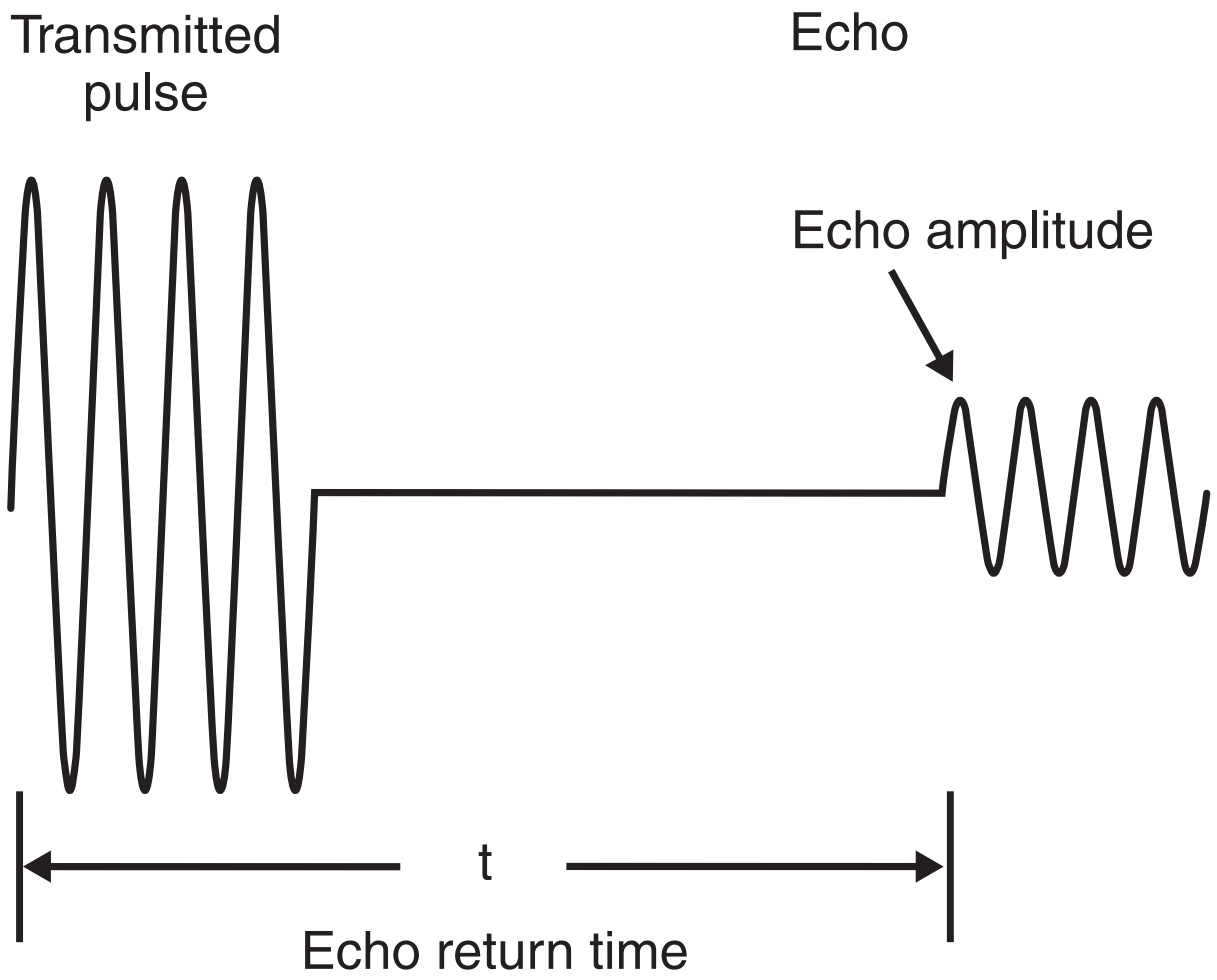

Figure 2. Echo amplitude and echo return time information obtained from an ultrasonic instrument for one beam direction toward the target.

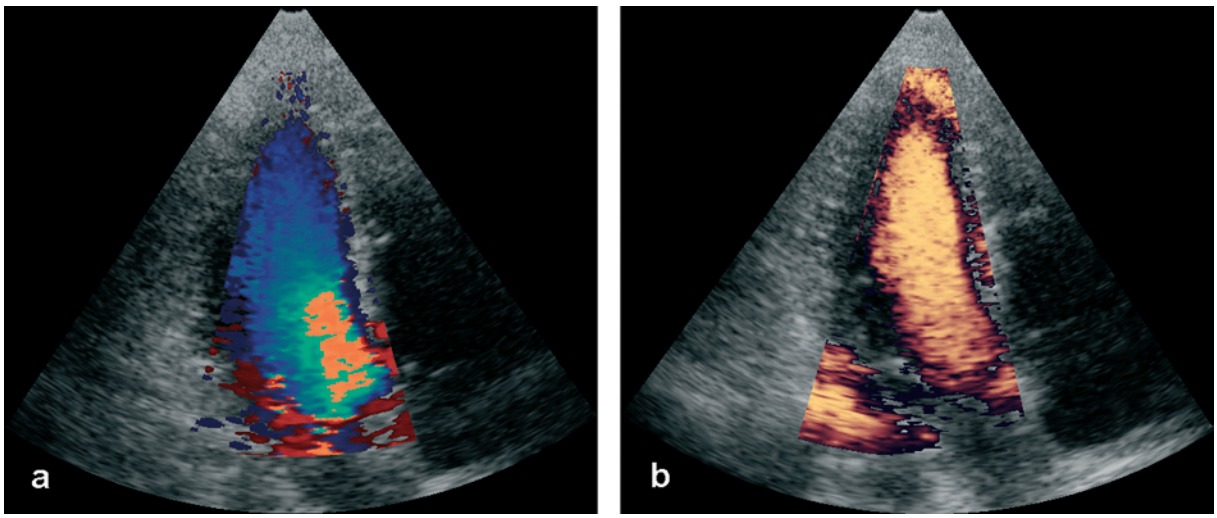

Figure 3. Doppler images produced by an ATL 5000 scanner, (a) a Colour Velocity Doppler image of blood flow in the left ventricle, (b) a Power Doppler image of blood flow in the left ventricle.

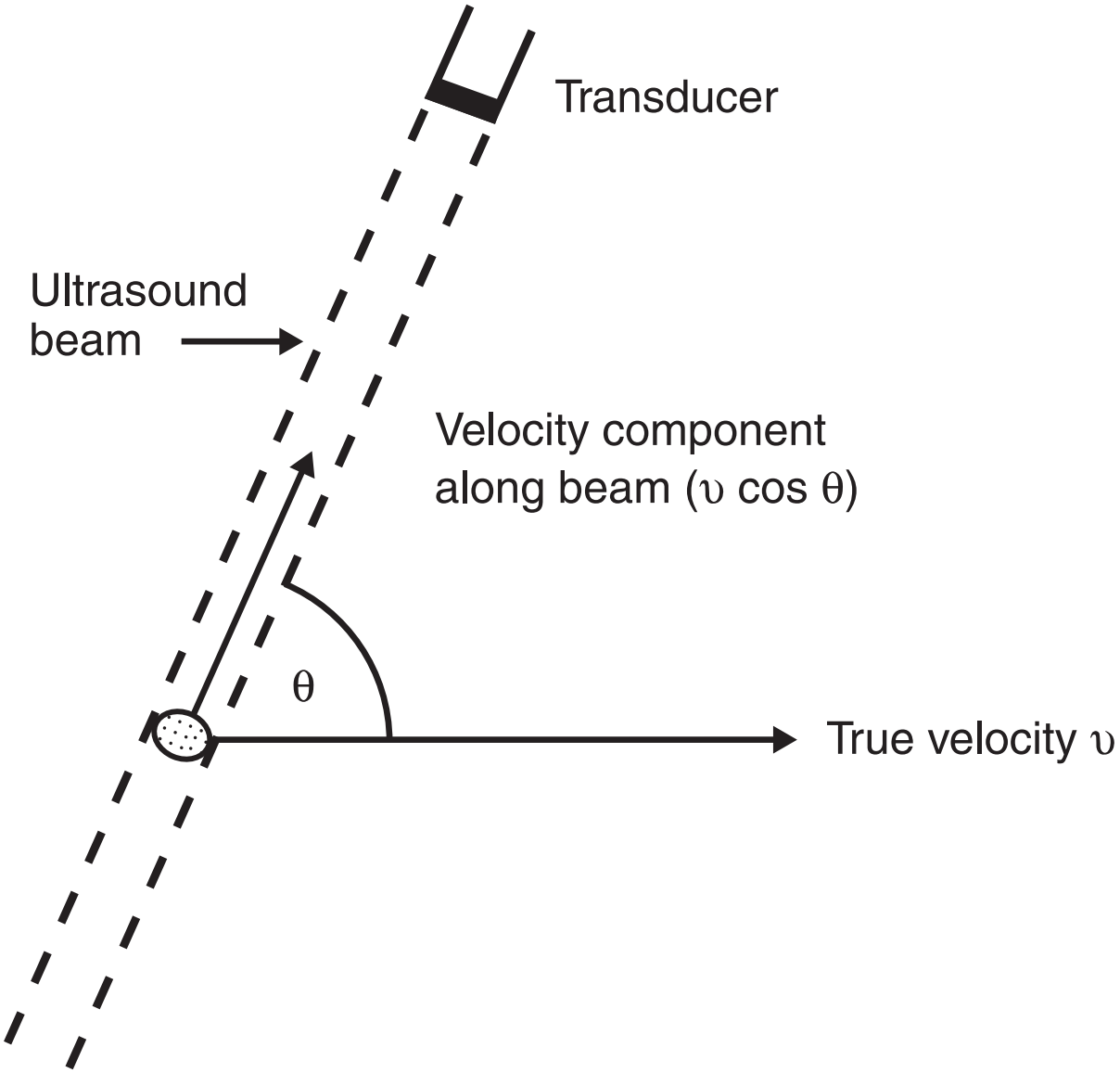

Figure 4. The component of velocity along the beam direction.

as 'aliasing'. The measurement of high Doppler shift frequencies due to high blood velocities requires echo signals to be collected at a high rate. However there is a limit to the rate at which echoes can be returned since time must be allowed between each pulse transmission for the related echoes to be collected. There is therefore an upper limit on the Doppler shift which can be measured and hence a corresponding upper limit on velocity. Velocities above the upper limit are calculated with the wrong value and direction of flow. The aliasing artefact appears as regions of wrongly coloured pixels in a Colour Doppler Velocity image.

Power Doppler images are relatively straightforward to interpret: the power level at each pixel is presented as a level of brightness. Since the power at each pixel is fairly similar, as noted above, the images have a uniform brightness except perhaps at vessel walls or in turbulent areas. The main attraction of Power Doppler Imaging is that it is a sensitive technique which is good for depicting flow in small vessels, it therefore gives more complete images of vascularity than Doppler Velocity Imaging. Power Doppler Imaging is also not prone to aliasing artifacts but this is not too surprising since it only indicates the presence of flow and does not attempt to measure velocity. Power Doppler images are not extensively used in cardiology. They can give some improvement to the definition of myocardial boundaries and hence be of value in stress tests. This improvement arises since averaging over a few consecutive images can be used to build up the power signal relative to noise and therefore enhance the depiction of blood at the myocardial boundary. Averaging does not improve the low velocity colour images at the boundary to the same extent since small velocity signals have different

directions and tend to cancel rather than build up relative to the noise. The use of power Doppler in cardiology could change with developments to show flow in vessels within the myocardium perhaps with the assistance of contrast agents.

Velocity direction and power information can be combined to produce Colour-coded Power Doppler images that show both power and the direction of flow. Although this type of image appears to make good use of direction and power information, to date it has not been widely used.

References

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