INTRODUCTION

Doppler ultrasound has been used to measure the blood flow velocity in vessels during the cardiac cycle in the fetoplacental, uteroplacental circulation and has been focused on arteries for the evaluation of downstream distribution of cardiac output (**Gembruch et al., 2003**).

Because no therapy at present has been shown to significantly improve placental function, the goal of prenatal testing is to optimize the timing of delivery, late enough to avoid the sequelae of iatrogenic severe prematurity, yet early enough to avoid fetal death (**Ferrazzi et al., 2002**).

Venous Doppler flow measurements have also been reported to allow for a more detailed analysis of the fetal circulatory and cardiac condition especially in the presence of abnormal arterial Doppler waveforms (**Pennati et al., 1997**).

The biophysical profile is an assessment of fetal wellbeing, it was affected by factors which suppress the fetal central nervous system such as hypoxia; its main disadvantage it is time-consuming taking up to 30 minute to complete the scan and little information is obtain (**Baschat et al., 2001**).

A normal reactive tracing antenatal cardiotocography is one in which the fetal heart rate reacts with two or more acceleration to movements or contraction within a 20 minute period, its main disadvantage is the same as biophysical profile (**Bilardo et al., 2004**).

A particularly useful characteristic of Doppler in comparison with biophysical profile or non stress test is that it provides information on a continuous scale, so that the progressive deterioration of the placental function and of the consequent fetal cardiac function can be monitored sequentially (**Francisco et al., 2006**).

Doppler studies of the umbilical artery alone are not diagnostic of hypoxia in high risk pregnancies as the sensitivity is low, a combination of conventional and Doppler ultrasound has a sensitivity, specificity, positive predictive value and negative predictive value (**Krapp et al., 2002**).

Ductus venosus flow plays a fundamental role in fetal hemodynamics, and In utero, it allows approximately 20 to 30% of the umbilical venous blood to bypass the liver and rapidly reach the central circulation and help maintain a stable flow of blood towards the brain, heart and adrenal glands (**Kiserud et al., 2000**).

The Ductus venosus acts as the first partition determining the proportion of umbilical venous blood that is diverted to the heart and the typical Ductus venosus waveform includes a peak during ventricular systole, a second peak during ventricular diastole and a nadir during the atrial contraction in late diastole (**Kiserud, 2005**).

Since the introduction of color Doppler imaging in 1991–1992, this small venous vessel has become the object of extensive clinical research in the human fetus, and the velocity waveform in the Ductus venosus has been proposed as a relevant indicator of fetal well-being (**Haugen et al., 2004**).

Previous reports describing blood flow velocities in the Ductus venosus have demonstrated an increase in the S-wave, D-wave and A-wave during pregnancy (**Bahlmann et al., 2000).**

Hypoxemia leads to increased umbilical venous pressure, with relative increase in blood flow through the Ductus venosus and decrease in the hepatic blood flow, the opening of the Ductus venosus in hypoxia might be a sign of fetal stress response (**Campbell et al., 2001**).

The Ductus venosus in the compromised fetus might be dilated due to central veins pressure and the nadir due to back pressure from the atrial contraction increased, resulting in absent or reversed flow (**Rizzo et al., 1996**).

The first reports on Ductus venosus blood velocity in complicated pregnancies have suggested a characteristic change in the blood velocity spectrum, with a decrease in end-diastolic blood velocity corresponding to atrial contraction and also found a correlation between abnormal Ductus vensous and signs of fetal hypoxemia (**Rizzo et al., 1994**).

Baschat et al., (2000) shows the relationship between Ductus vensous flow and the brain-sparing phenomenon has been studied in human fetuses during hypoxia. In addition to the study of Baschat et al have demonstrated that abnormal Doppler findings at the Ductus venosus can predict cord acidosis, perinatal death, or major neonatal morbidities (**Bahado-Singh et al., 1999**).

Nevertheless more data is needed to asses the value of Ductus venosus Doppler in prediction of fetal hypoxia in high risk pregnancies.

AIM OF THE WORK

The aim of this study is to find out if Ductus venosus Doppler velocimetry may give earlier indication of fetal hypoxia than does Umbilical and middle cerebral artery blood velocity.

DOPPLER ULTRASOUND

Introduction

Ultrasound technology has evolved from only producing images of the pregnancy to now include methods for measurement of both maternal and fetal circulatory functions. The phenomenon of Doppler Shift of ultrasonic echoes forms the technical basis for acquisition of information on the maternal-fetal hemodynamic circulations ***(Nicolaides et al., 2006).***

Johann Christian Andreas Doppler (November 29, 1803 - March 17, 1853) was an Austrian mathematician and physicist, most famous for the hypothesis of what is now known as the Doppler Effect which is the apparent change in frequency and wavelength of a wave that is perceived by an observer moving relative to the source of the waves. **Satamura** was the first describing clinical application of Doppler U/S technology in 1959 **(Rosenberg, 1997).**

Ultrasound transducers operate on the principle of piezoelectricity, by which certain materials produce a voltage when deformed by applied pressure and produce a pressure when voltage is applied. The frequency of sound, called resonance frequency is equal to the frequency of the driving voltage ***(Lee et al., 2003)***.

For each pulse of ultrasound, a series of echoes are returned as the ultrasound pulse is reflected off objects at a greater or lesser distance. These echoes are received by the transducer and converted into electrical energy, which is processed electronically and displayed as a series of dots in a single scan line on the display ***(Nicolaides et al., 2006)***.

Additional pulses traveling along the same path result in the same scan line being displayed, but if the starting point for each subsequent pulse is different while the direction of the path is unchanged, a cross sectional image builds up. The rectangular display that results is called a linear scan ***(Lee et al., 2003***).

Doppler technique has been introduced in medicine for many years; this diagnostic modality has gained an importance in obstetrics ***(Kurjak and Kupesik, 2004).***

In recent years, the capabilities of ultrasound flow imaging have increased enormously. Color flow imaging is now common place and facilities such as ‘power’ or ‘energy’ Doppler provide new ways of imaging flow ***(Kurjak and Kupesik, 2004).***

The Doppler Effect

For all waves such as sound or light, the Doppler Effect is a change in the observed frequency of the wave because of motion of the source or observer. This is due to the source stretching or compressing the wave or the observer meeting the wave more quickly or slowly as a result of their motion ***(McDicken et al., 2002)***.

In basic medical usage of the Doppler Effect, the source and observer (receiver) are a transmitting and receiving crystal usually positioned next to each other in a handle-held transducer. A continuous cyclic electrical signal is applied to the transmitting crystal and therefore a corresponding continuous wave ultrasound beam is generated when the ultrasound is scattered, or reflected at a moving structure within the body ***(McDicken et al., 2002)***.

A continuous cyclic electrical signal experiences a Doppler shift in its frequency and return to the receiving crystal. Motion of the reflector towards the transducer produces an increase in the reflected ultrasonic frequency, while motion away gives a reduction. When the line of movement of the reflector is at an angle 0 to the transducer beam the Doppler shift frequency (FD) is given by:

$$FD = Ft - Fr = Ft\,(2.\cos\theta) / C$$

Where Ft is the transmitted frequency

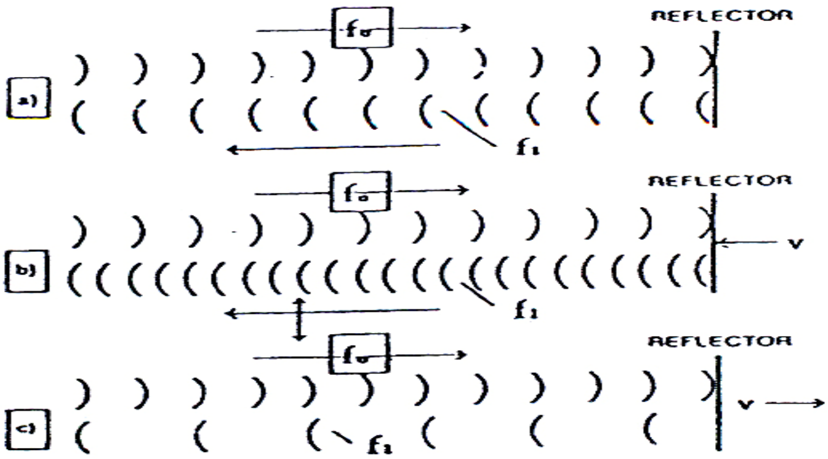
Fr is the received frequency

C is the speed of ultrasound.

(2. Cosθ) is the component of the velocity of the reflecting Agent along the ultrasonic beam direction ***(Nicolaides et al., 2006)***.

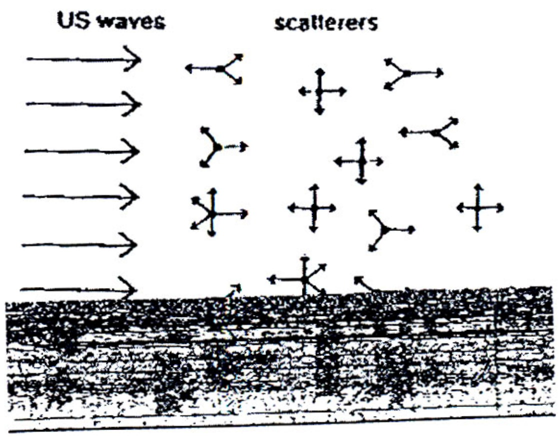
For successful application of Doppler in medical diagnosis, an understanding of Doppler physics is necessary; the basic principle of the Doppler Effect for a case when the waves reflect from a reflector, If the reflector does not move called (case a), the frequency of the reflected wave (Fr) is equal to the transmitted frequency (Ft) ***(Fontaine and Clautier, 2003)***.

If the reflector moves towards the transceiver, the reflected frequency will be higher than the transmitted called (Case b), while in case that the reflector moves away called (case c), from the transceiver the received frequency (Fr) will be lower than the transmitted (Ft). This frequency change FD (called the Doppler shift) is proportional to the velocity V of the reflector movement, Doppler shift is expressed in Hz ***(Fontaine and Clautier, 2003)***.



(Fig 1) illustration of the Doppler Effect (Kurjak and Kupesik, 2004).

In medical applications, the Doppler Effect is usually used by intonating the moving blood and assessment of the Doppler shift of ultrasound scattered on erythrocytes ***(Kurjak and Kupesik, 2004).***

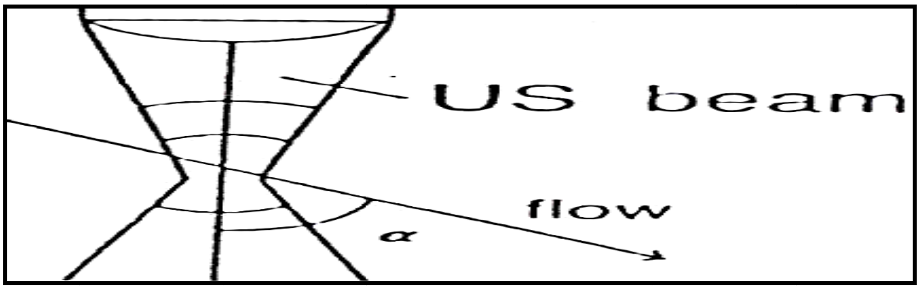


(*Fig 2*) Scattering of ultrasound yields multiple back scattered wavelets *(Kurjak and Kupesik, 2004).*

Each single erythrocyte reflects (retransmit) ultrasound in various directions, but the back scattered energy is sufficient for velocity assessment ***(Kurjak and Kupesik, 2004).***

The general method of measurement consists of transmission of bundled ultrasound into the body at a general angle (a) to the flow ***(Fontaine and Clautier, 2003)***.

In practice, the best results of Doppler ultrasound are obtained at an angle between 30^o and 60^o ***(Fontaine and Clautier, 2003)***.



(Fig 3) **Relation between ultrasound beam and the flow** ***(Kurjak and Kupesik, 2004).***

There is an upper limit to the Doppler shift that can be detected by pulse instruments. If the Doppler shift frequency exceeds one-half the pulse repetition frequency, a phenomenon called aliasing occurs, in which the peak of the velocity waveform appears below the baseline ***(Nicolaides et al., 2006)***.

The width of the Doppler ultrasound volume box, compared to the width of the vessel wall, may also affect velocity estimation. In small vessels, the average velocity may be only one-half the velocity at the centre of the stream, because of turbulence caused by friction from the vessel wall ***(Nicolaides et al., 2006)***.

Volume box widths which are too small in relation to vessel size and which are aimed at the centre of the stream may result in overestimation of velocity Volume box widths that are available usually start at 1 mm and increase to 10 mm in 1 mm increments ***(Fontaine and Clautier, 2003)***.

The characteristics of an ultrasound beam, the propagation of ultrasound in tissue and the design of the transducer as found in B-mode imaging are all relevant for Doppler techniques ***(McDicken et al., 2002)***.

It is possible to transmit and receive ultrasound waves continuously with a probe that contains a transmission transducer and a reception transducer (CW) Another possibility is to transmit in the form of pulses whose Doppler shift is measured after the time necessary for ultrasound to reach a defined depth in the body (PW) ***(Fontaine and Clautier, 2003)***.

Instrumentation for Doppler Measurements:

A number of techniques have been developed which use the shift in frequency of ultrasound when it is reflected from moving blood. This frequency shift is known as the (Doppler Effect). Four types of diagnostic Doppler instrument are usually distinguished ***(McDicken et al., 2002)***.

- Continuous wave Doppler (CW).
- Pulsed wave Doppler (PW).
- Duplex Doppler.
- Power Doppler.

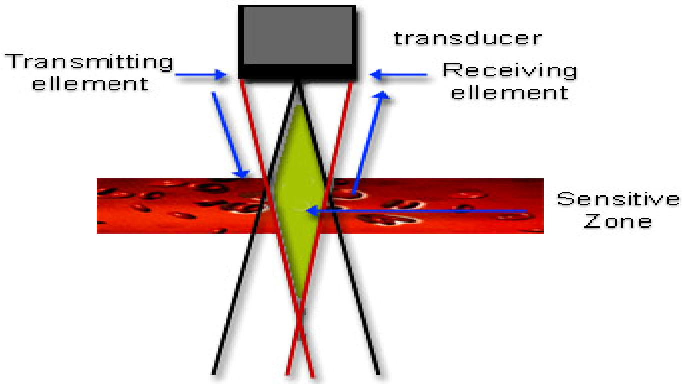
- ***Continuous wave Doppler (CW):***

The (CW) system has no depth resolution so that the measurement results of all flows along the line of sight add together and mix. On the other hand this system measures well all (fast and slow) velocities. If there is only one blood vessel along the line-of- sight or one flow is dominant the (CW) system is very good for practice ***(Kurjak and Kupesik, 2004).***

This can measure a wide range velocity without limit. The transducer contains two crystals. One transmits the ultrasound beam continuously and the second receives the back scattered echo. Such machines are essentially fetal heart detectors, attached to a device, which visually displays these audibly received signals (the spectrum analyzer) ***(McParland and Pearce, 1990).***

The advantage of continuous wave equipment is that it is relatively inexpensive and portable. The main disadvantage is that the vessel being studied cannot be simultaneously visualized ***(Hoskins, 2002).***

However, this can usually be overcome because the umbilical and uteroplacental vessels both in health and disease have characteristic signals, which are easily recognized. Abnormal vascular anatomy makes interpretation of information obtained from simple continuous wave system difficult ***((Hoskins, 2002).***



(Fig 4) Continuous -wave Doppler transducer (Powis and Schwartz, 1991).

- ***Pulsed wave Doppler (PW):***

If, however, one must measure the flow in a single blood Vessel, the (PW) system can measure within a well-defined sensitive volume. The sensitive volume has a length that depends on the pulse length (in time) and a width that depend on the beam width (and focusing) ***(Kurjak and Kupesik, 2004).***

Pulsed-Doppler systems have the ability to select the depth from which Doppler information is received, thus allowing analysis of blood flow within a single vessel. To do this, the vessel to be studied is first located with continuous wave ultrasound. Next, a gate is placed over the vessel which passes only signals that are returned within a defined time ***(Hoskins, 2002).***

The width of the gate (also called the volume box) is adjusted to the diameter of the vessel The returning Doppler frequency shift echoes are be convened electronically by a mathematical technique called fast fourier transformation and displayed as the Doppler shift versus time waveform ***(Kurjak and Kupesik, 2004).***

The same transducer is used, to transmit and then to listen for the returning signal. By only allowing the equipment to receive echoes for a short period, the depth from which the echoes arise can be precisely determined. The combination of pulsed Doppler and real-time ultrasound is known as a duplex system, and allows simultaneous imaging at low pulse repetition frequently, usually less than 2.5 KHz ***(Chen et al., 2004).***

The sequence of transmitting and then receiving signals needs to be repeated to build up the Doppler signal. The rate at which pulses of ultrasound are emitted is known as the pulse repetition frequency (PRF) ***(Boitos et al., 2002).***

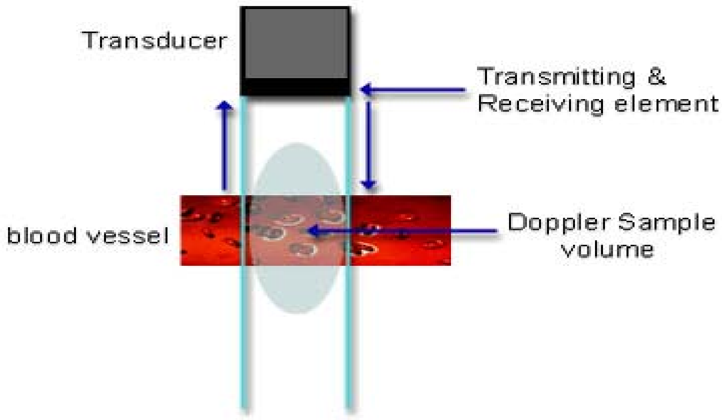
The higher the PRF the more pulses will be available per cycle, thus giving a better quality signal. However, the PRF is limited, as there must be sufficient time to collect all echoes from one pulse prior to emitting a further pulse. This restriction on the PRF is dependent on the depth of the sample volume, the maximum PRF being given by the formula**.**

PRF (Hz) = (c.d.)/2

Where (c) is the velocity of sound in tissue (l540mls) and (d) is the depth (cm) of the structure being investigated ***(Chen et al., 2004).***

The minimum PRF allowable must be twice the frequency of the Doppler signal. If the PRF is lower, aliasing is produced, and failure to obtain the proper signal occurs ***(Boitos et al., 2002).***

Aliasing is a problem only with instruments that use pulsed sampled techniques, not continuous, and is corrected by increasing the frequency or increasing the angle up to 60 ***(Boitos et al., 2002).***



(Fig 5) Pulsed-wave Doppler transducer (Powis and Schwartz, 1991).

Doppler ultrasound in general and obstetric ultrasound scanners uses pulsed wave ultrasound. This allows measurement of the depth (or range) of the flow site. Additionally, the size of the sample volume (or range gate) can be changed. Pulsed wave ultrasound is used to provide data for Doppler sonograms and color flow images ***(Soustiel et al., 2002).***

- ***Duplex method:***

In duplex system, the transmitted ultrasound frequency in the Doppler mode is often lower than that for B-mode. The low Doppler beam frequency is to enable higher velocities to be handled before aliasing occurs, while the high B-scan frequency is to optimize resolution in the image ***(McDicken et al., 2002)***.

- ***Power Doppler :***

2D Power Doppler.

3D Power Doppler.

It is another modality in which it displays areas with moving structures in colors. The color means that, there is flow in the area and the brightness of the color qualitatively indicates the quantity of moving erythrocytes, it does not define the direction of blood flow. The virtue of that display mode is that, it shows about equally fast and slow flow, so that we can get the idea about general blood perfusion in some area ***(Chen et al., 2004)***.

<u>Doppler Indices:</u>

The most common Indices used to distinguish patterns associated with high and low resistances to blood flow are:

(1)The systolic / Diastolic ratio (S/D) ratio.

(2)The pulsatility index (PI), also called the impedence index.

(3)The resistance index (RI), also called the Pourcelot ratio.

Resistance index (RI) = S -D/S

Pulsatility index (PI) = S-D/MEAN ***(Chen et al., 2004)***.