The correlation between elevated Middle cerebral artery peak systolic velocity among other Doppler indices and bad fetal outcome

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Abstract

Brain sparing is strongly correlated with increasing placental vascular resistance both on the fetal and maternal sides of the placenta as showen by high operative delivery and fetal distress rate

Key words:

Fetus, Hypoxia, Parental Outcome , Ductus Venous , Umbilical Venous Pulsation

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LIST OF ABBREVIATIONS

AEDV Absent End diastolic velocity

AVRI Averaged Resistance Index

BFC Blood Flow Classification

BPS Biophysical Profile Scoring

DV Ductus Venosus

FHR Fetal Heart Rate

GV Galen Vein

IUGR Intra-uterine Growth Retardation

MCA Middel cerebral artery

NICU Neonatal Intensive-Care Unit

PI Pulsatility Index

PIV Pulsatility Index for Veins

RAP Right Atrial Pressure

REDV Retrograde Diastolic Velocity

RI Resistance Index

S/D Systolic/Diastolic ratio

SGA Small for gestational age

STV Short-Term Variation

TUVF Total Umbilical Venous Flow

UA PI Uterine arterydoppler pulsatility index

UAS Uterine artery Score

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INTRODUCTION

Doppler ultrasound provides a non-invasive method for the study of fetal hemodynamics. Investigation of the uterine and umbilical arteries gives information on the perfusion of the uteroplacental and fetoplacental circulations, respectively, while Doppler studies of selected fetal organs are valuable in detecting the hemodynamic rearrangements that occur in response to fetal hypoxemia.

The fetus redistributes its blood flow to protect the vital organs heart, brain and adrenals at the expense of nonessential vascular beds ***(Behrman et al., 1970).*** Fetal cerebral Doppler then shows a higher diastolic blood velocity as a reflection of diminished impedance to flow in the cerebral circulation ***(Mari et al., 1992; Wladimiroff et a.l, 1987).*** This phenomenon is called brain sparing. Increased peak systolic blood velocity (PSV) in the middle cerebral artery has recently been related to adverse perinatal outcome, ***(Mari et al., 2007)***

In the fetal central venous circulation, much focus has been paid to ductus venosus and inferior vena cava and even the role of the umbilical vein has been suggested for monitoring fetal condition. Doppler surveillance of cerebral veins especially pulsatility pattern in the Galen vein blood velocity related to adverse outcome of pregnancy has also been studied ***(Ferrazzi et al., 2002)***. Blood flow in all the above-mentioned placental and fetal vessels have been studied, but they have not been compared in predicting outcome of pregnancy in the same group of high-risk cases.

Aim of work

To evaluate the correlation between elevated middle cerebral artery peak systolic velocity among other Doppler indices and adverse forms of bad fetal outcome.

Review of literature

Chapter 1:

Physical principals for Doppler ultrasound:

This chapter demonstrates concisely the basic concepts of Doppler and Doppler indices, which is a must to understand their diagnostic utility. Despite the fact that this research is based on a clinical study to explore applied Doppler technology significance, developing an understanding of the fundamental principles is indispensable for its proficient use. Umbilical ,uterine and middle cerebral artery hemodynamic circulations and Doppler wave interpretation will be explain to draw a general picture of clinical diagnostic significance of Doppler sonography in obstetrics.

Doppler Effect:

It is the phenomena of observed changes in the frequency of transmitted waves' energy when relative motion occurs between the source of wave transmission and the observer. The observed change in frequency was named the Doppler shift by **Christian Andreas Doppler**.

$f_d = f_t - f_r$

Where f_d is the Doppler shift, f_t is the transmitted frequency, f_r is the received frequency.

When the source of frequency and the observer move closer the wavelength decreases while the frequency increases and vice verse. The utility of the Doppler Effect is grounded on the fact that shift in frequency is proportion to the speed of movement between the source and the receiver, so accordingly can be used to assess the speed. The movement of the source or the receiver doesn't affect the Doppler Effect. ***(Maulik et al., 2005)***

Doppler Ultrasound

The first medical applications of Doppler sonography were initiated during the late 1950s, and impressive technologic innovations have been continuing ever since.

The phenomenon of Doppler Effect is observed also when an ultrasound beam come across a blood flow. Within blood circulation, millions of red blood cells act as moving scatterers of the ultrasound beam. When this occurs, the erythrocytes act first as moving receivers and then as moving sources, forming the basis of the Doppler equation:

$F_d = 2f_t\ v/c$

Where F_d stands for the frequency shift, f_t the transducer frequency, v the velocity of the scatterer in a given direction and c the propagation speed of sound in the medium.

If the transducer makes an angle (θ) to the direction of the blood flow, the v in the Doppler effect equation is measured by cosine of the angle θ(cos θ).

$F_d = 2f_t * \cos\ \theta * v/c$

The velocity of the blood flow can be determined by:

$V = F_d * c/2f_t * \cos\theta$.

Thus if the angle of the beam incidence and the Doppler shift are known, the velocity of the blood flow can by known, assuming that the transducer frequency and the velocity of sound in tissue remain relatively constant.

The above formula represents the base for clinical application of the Doppler principle. (***Sohn et al., 2003)***

Back scattering

The process of ultrasound wave reflection, known as scattering can be explained by Rayleigh phenomena observed in light waves.

Rayleigh scattering :(named after Lord Rayleigh) is the scattering of light or other electromagnetic radiation by particles much smaller than the wavelength of the light. It can occur when light travels in transparent solids and liquids, but is most prominently seen in gases.

Rayleigh scattering of sunlight in clear atmosphere is the main reason why the sky is blue. Rayleigh and cloud-mediated scattering contribute to diffuse light (direct light being sunrays). ***(Van de Hulst et al. ,1981)***

One characteristic of Rayleigh scattering is that intensity of the scattered energy (I) is proportional to the fourth power of the frequency.

$I \sim f_4$

The observed frequency dependence on the power or intensity makes it important to select the appropriate transducer frequency for Doppler applications. (***Sohn et al., 2003)***

Thus raising the transducer frequency from 3 MHz to 4 MHz leads to fivefold augmentation of the scattered echo intensity. Yet the disadvantage of this is the limitation to measure deep lying blood vessels, as a higher frequency leads to greater attenuation. In order to balance these two effects an optimal frequency of 2-3 MHz was found to reach deep lying vascular targets in the fetus in fetus Doppler insonations via the maternal abdomen. While via transvaginal approach where the transducer lies approximate to highly vascular pelvic structures like the uterine and the ovarian arteries, the use of higher frequency seems to increase the sensitivity without significantly attenuating the beam. (***Sohn et al., 2003)***

When the propagating ultrasound wave encounters an acoustic surface it is reflected. Scattering happens when the interface is smaller than the propagated sound wavelength. Such an interface is known as a "point target". The Doppler ultrasound wave shifted from a moving interface scatters in all directions with availability to reach any receiving transducer at the source of transmission. Backscattering refers to returning scattered waves to the source receiver. (***Sohn et al., 2003)***

It is well established that RBCs are the primary source of scattering in the circulation as they represent the vast majority of cells in blood vessels in comparison to WBCs and platelets. (***Sohn et al., 2003)***

A typical human erythrocyte biconcave disk has a diameter of 6–8 µm and an average thickness of 2 µm, much smaller than most other human cells. In comparison the wavelength of diagnostic Doppler ranges between 1540 µm and 154 µm corresponding to 1-10 MHz transducer frequency. As is crystal clear, RBCs are several magnitudes smaller than the wavelength creating classic point targets. The number of RBCs in such an ample scattering volume fluctuates around a mean value and causes fluctuations in the scattering power .Blood flow turbulence induces increased fluctuation in the RBCs concentration which is reflected with increased scattering power and consequently the power of the Doppler shift signal. ***(Shung et al., 2005)***

Another factor which has influence on scattering is the state of red cell aggregation. Spatial variations in the blood field can lead to variation in red cell packing and backscattering cross section which affects the Doppler power at a given frequency. ***(Bascom et al., 1996; Fontaine et al., 2003)***

In this case, the mean Doppler frequency will not necessarily reflect the mean blood flow which disturbs volumetric flow quantification. Scattering phenomena is complex and a comprehensive view is beyond the scope of this chapter.

The relation between angle of insonation and Doppler shift

It is evidence based that when the ultrasound beam transects the vessel axis, Doppler shift is received in the best form .As the angle increases the frequency shifts reversal proportionately decreases, until it disappears when the angle reaches 90º. ***(Balbis, et al., 2007)***

Umbilical Artery anatomy:

Umbilical arteries are formed in the embryo from the primitive vitelline arteries after they form a plexus on the sides of the hind-gut on the wall of the endodermal vesicle. Vitelline arteries originate from the ventral aspects of the primitive dorsal aorta not far from it caudal end. The meeting point of the caudal ends of the primitive dorsal aorta and the vitelline arteries plexus forms the origin of the umbilical artery. This happened when the embryo is just 13-16mm long. After this the vitelline and umbilical circulation are separated. Two umbilical arteries are well formed springing by a number of roots which anastomose together, from the caudal part of the corresponding dorsal aorta. (***Sohn et al., 2003)***

A reliable Doppler signal from the umbilical artery can by obtained transvaginally by the 7th week ***(Arduini et al., 1991a)*** and transabdominally by the 9th week of gestation and a persistent diastolic component increases indicating decreased resistance. After 12 gestational weeks, the diastolic blood flow component becomes progressively present and should be present in all pregnancies after 16 weeks. From 20 gestational weeks onwards, the growth of the placental unit with an increase in the number of functioning vascular villi decreases its vascular impedance ***(Trudinger et al., 1985a)***. In humans, umbilical blood flow increases in direct proportion to the increase in human fetal body weight, so that weight-indexed flow remains approximately constant at 110 ml/min/kg to 125 ml/min/kg over the last third of the pregnancy ***(Gill et al., 1981; Sutton et al., 1990)***. The blood velocity wave form indices decrease nearly linearly as the pregnancy approaches term (***Thompson et al., 1988; Arduini et al., 1990)***.

In the third trimester, the umbilical arteries are extensions of the internal iliac (hypogastric) arteries and extend from the pelvis to umbilicus in the anterior abdominal wall deep to the rectus muscle and fascia. The S/D ratio is normally less than 3.0 and the RI less than 2/3 in the last trimester. In the umbilical artery no significant difference in the PI between the two behaviour states 1F and 2F is seen ***(Van Eyck et al., 1987)***.

In post-term pregnancies the umbilical artery Doppler velocimetry is not altered even in the presence of other signs suggesting fetal compromise ***(Guidetti et al., 1987; Farmakides et al., 1988)***.Uterine contractions, artificial rupture of the membranes or the infusion of oxygen during an uncomplicated labour do not alter placental vascular resistance to fetoplacental blood flow ***(Stuart et al., 1981; Fleischer et al., 1987; Fairlie et al., 1989)***. During labour there is no correlation between abnormal Doppler S/D ratios and adverse fetal outcome ***(Sarno et al., 1989; Malcus et al., 1991)***. Abnormal umbilical artery blood velocity waveforms in humans are associated with a decrease in the number of small muscular arteries in the placental tertiary stem villi ***(Giles et al., 1985)***. These morphologic changes may deteriorate the placental oxygen and other nutritional transport, and lead to FGR. Abnormal umbilical artery findings