DOPPLER ULTRASOUND

Clinical applications in the adult and the foetus

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The application of Doppler signals in medicine has been available for the past 25 years. The Doppler effect is the change in frequency of waves when there is a relative movement between source and observer. The technology used in medical Doppler is capable of profiling the pattern of flow within specifically identifiable vessels (Jaffe 1984). This therefore should have several applications in different branches of medicine.

The use of Doppler Studies in the examination of patients with peripheral vascular disease was first reported by Satomura in 1959. Doppler technology has provided the clinician with a means for the quantitative assessment of the severity of arterial occlusive disease. This non-invasive technique provides objective and repeated assessments relating to the long term prognosis following reconstructive surgery.

Doppler ultrasound has provided a versatile technique for use in the diagnosis of disorders of the venous system. Screening of the deep venous system of the lower extremity using this portable method needs considerable attention to detail but is quick and simple to learn.

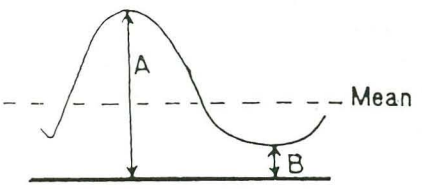
The use of Doppler ultrasound is a good adjunct to echocardiography in the evaluation of patients with cardiac disease. These techniques reduce the need for invasive investigations and aid in the proper timing of surgical procedures.

Transient and permanent cerebrovascular ischaemic events may be associated with either haemodynamically significant carotid artery stenoses or nonstenotic carotid plaques that serve as sources of microemboli. Duplex scanners, that is real time B-scan imaging coupled with pulsed range-gated Dopplers, are noninvasive devices which have helped in the grading of stenotic lesions (Dreisbach). The development of an accurate computerised method for the interpretation of the carotid artery waveform has reduced the subjective evaluation, and therefore increased the sensitivity of this technique. This may help in screening which segment of the population is at greater risk of developing a stroke. Duplex scanning is a cost effective noninvasive neurovascular test for evaluating carotid bifurcation disease.

There is a wide spectrum of applications of Doppler ultrasound in the abdomen. There is good evidence that the use of small, hand-held Doppler units in the operating room is of value in detecting regional blood flow in the kidney and the gastrointestintestinal tract. Doppler ultrasound has been applied in the investigation of renal arteries. This is especially important in the early post-operative assessment of renal transplant function. Renal transplant main vessel vascular occlusion must be diagnosed early in order for remedial surgery to be successful. Doppler ultrasound may become the examination of choice for distinguishing between acute tubular stenosis and transplant rejection.

Apart from other applications in medicine the Doppler effect has been a useful noninvasive repeatable technique to assess foetal and uteroplacental circulations. This is clinically useful in the investigation and management of complicated pregnancies, in particular intrauterine growth retardation (I.U.G.R.) and pregnancy induced hypertension (P.I.H.).

The blood flow in the umbilical vessels gives rise to a characteristic waveform. Using continuous wave Doppler equipment directed at the umbilical vessels, both the sound and the waveform shape are recognised. The flow velocity waveforms can be analysed by comparing the systolic or peak (A) and the diastolic or trough (B) of the frequency shift. There are three commonly used ratios:



$\frac{A}{B}$ = A/B ratio (Stuart et al 1980)

$\frac{A - B}{A}$ = Resistance index (Porcelot 1974)

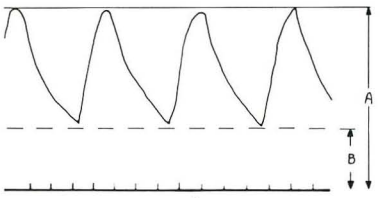
$\frac{A - B}{Mean}$ = Pulsatility index (Gosling and King 1975)

The normal A/B ratios vary with gestation, at 28 weeks the A/B ratio is 5 or less, decreasing to a value of 4 at 34 weeks and 3.5 or less between 34 weeks to term. The Resistance Index should be less than 0.5 in normal pregnancy. Although the Pulsatility Index seems to be the most accurate, it requires a computer programme whilst the first two ratios can be calculated simply. The Pulsatility Index is 2.41 + 0.3. in high risk pregnancy while it is 1.99 = 0.2 in pregnancies which are low risk.

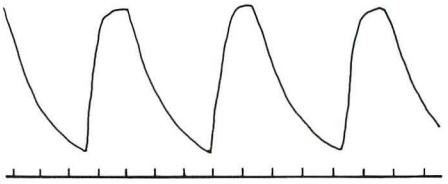
The most important characteristic of the waveform is the trough which represents the end-diastolic flow. As normal pregnancy progresses, an increase in the end-diastolic volume occurs due to a decrease in the foeto-placental resistance. Developmentally, the appearance of the end-diastolic flow coincides with the invasion of the myometrium by the cytotrophoblast. In I.U.G.R. and P.I.H. there is an increase in the resistance which in turn results in a reduction in the end-diastolic flow. When the disease is severe, the trough may reach the zero mark or even become negative (see waveform diagrams). It is also noted that a diastolic notch that is normally only present until the 26th week, tends to persist in I.U.G.R. and P.I.H. indicating reduced vessel compliance.

Umbilical flow was noted to be high in patients with Rhesus iso-immunisation and in ante-partum haemorrhage. In patients with a low end diastolic flow there is an increased risk of neonatal morbidity (Pearce 1989).

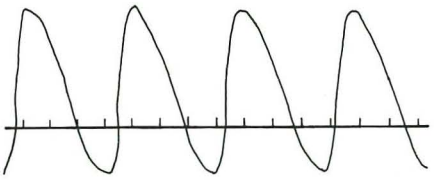
Uterine and arcuate artery blood flow may also be reduced in patients with P.I.H. and I.U.G.R. in whom there is placental insufficiency due to impaired utero-placental circulation (Rightmire 1988). The blood flow in the uterine artery has been found to be reliable in the diagnosis of I.U.G.R. while arcuate artery blood flow may forecast foetal distress during labour. Blood flow in the foetal aorta and carotid arteries may be quantified. In asymmetrical growth retardation, there is a brain sparing effect in which the blood is shunted to the brain thus reducing the pressure ratios in the descending aorta. The abnormal flow velocity waveforms in the descending aorta seem to precede the changes in the umbilical vessels. Moreover, the reduction in the end-diastolic flow in the descending aorta suggests chronic ischaemia of the splanchnic and renal circulations. This would predispose to necrotising enterocolitis in the newborn. The concomitant reduction in the renal circulation results in less urine production and hence oligohydramnios.



A: Normal tracing



B: Abnormal tracing A/B > 6



C: Abnormal tracing A/B > 6 with reverse flow

Sketch of umbilical artery flow velocity-time waveforms in which the vertical dimension represents the Doppler-shifted sound frequencies (Hz) and the horizontal dimension represents time. Waveforms presented below the broad horizontal line represent flow in the direction opposite to that above the line: **A**, normal umbilical artery flow velocities over umbilical vein flow velocities at 34 weeks gestation; **B**, waveform characterized by a high A/B ratio indicative of high impedance with low end diastolic velocities that approach the limits of the high-pass filter; **C**, very abnormal waveform with reversal of the direction of flow in diastole as indicated by the segment of the arterial waveform in each cardiac cycle which appears below the broad horizontal line.

Absent end-diastolic velocity in the umbilical artery indicates poor foetal prognosis in general but it does not indicate imminent foetal death, and may improve. Low end-diastolic flow values occur approximately one week before the first abnormal trace. It is encouraging to note that absent end-diastolic velocity does not occur within a week of having a normal umbilical waveform. Therefore Doppler waveform studies may be repeated weekly. This may be a good predictor of foetal risk, allowing for timely intervention.

The study of Doppler velocity waveform is a relatively noninvasive investigation of the foeto-placental circulation which may help in the reduction of perinatal morbidity. Doppler waveform studies may become a new tool in the screening of high risk groups in early pregnancy, since changes in the waveform predate conventional tests of foetal wellbeing.

References

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