Duplex Doppler and Colour Flow Mapping Ultrasound in the Evaluation of Acute Scrotal Disease

Thesis

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بسم الله الرحمن الرحيم

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INTRODUCTION
AND
AIM OF THE WORK

Acute painful scrotal disease may present a difficult challenge to experienced clinicians. An ideal imaging technique would allow correlation of anatomy with perfusion data.

Duplex Doppler ultrasound is ideally suited for diagnosing acute scrotal disease in which anatomy correlated with blood flow provides the information necessary to recommend appropriate management.

The aim of this work is to lie stress on the role of Duplex Doppler ultrasound in diagnosing acute scrotal disease and to define its position in the management of these cases. ***(Lerner et al., 1990).***

PHYSICS

Physics of Duplex Doppler and colour Doppler Ultrasound

Although many types of instruments present the Doppler shift as frequency shift (in kilohertz), comparsion between measurements made in different instruments is difficult because the transducer frequency and the angle may be different. Doppler shifts are only comparable when frequency and angle are given. More recent equipment display the velocity directly and includes the angular correction ***(Walter et al., 1986).***

Doppler Equation:

$F = 2f_0 \, V\cos 0/C$

where

F = Doppler frequency shift,

f_0 = the incident frequency,

V = the flow velocity,

C = the speed of sound in tissue,

0 = the angle between the ultrasound beam & the flow direction. ***(Tayler and Holland, 1990).***

In principle it is possible to estimate the velocity of a moving object emiting or reflecting sound (or ultrasound) waves from the measured Doppler shift by solving this equation.

Continuous wave Doppler:

Continuous wave Doppler instruments utilize two transducers, one to emit a continuous beam of ultrasonographic waves, and the other is to receive the reflected echo. This system is easy to use, needs very little patient cooperation and requires less technical skill to perform and interpret than other systems. Another advantage is that it has no limit on maximum measurable velocity. There is no gating of the signals, and the returing echo can be monitored continuously, thus eliminating the problem of aliasing that occurs when high frequency shifts are sampled with pulsed Doppler systems. ***(Crummy et al., l979).*** This system lacks the depth resolution and cannot distinguish Doppler signals from different vessels within the scanning field. Another limitation is that it is not accurate with degrees of stenosis less than 50 percent ***(Zwiebel and Crumy, l98l).***

Processing of Data:

Continuous wave Doppler signals may be processed by one of the following techniques:

1. Audible interpretation of the signal.
2. Analogue recording of the velocity signals.
3. Sound spectrum analysis.

l. Audible interpretation:

The signals may be interpreted using a stethoscope-type earpieces, ear phones or loudspeakers. An experienced observer learns to distinguish the audible signal characteristics that detect not only difference in arterial and venous flow, but also the presence or the absence of vascular disease and flow disturbances. However the audible interpretation of the signals requires considerable experience for maximal accuracy.

2. Analogue recording:

The most common device to translate Doppler frequency shift into voltage changes for analysis recording is the zero-crossing meter. With this device the averge frequency shift is determined and converted to a propotional electrical signal for recording on a strip chart recorder. Although such analysis recordings are relatively inexpensive, several limitations of the technique must be regarded. The recordings may be significantly altered by changes in the probe vessel angle, misalignment of the probe and the vessel, presence of broad frequency spectrum which is particularly met with disturbed or turbulent blood flow, mixture of arterial and venous signals vessel wall motion and varying velocities profile.

The instantaneous maximum velocity which represents the velocity of the fastest moving red cells may be also used for wave form recording. It is easier to obtain clinically and can be used for quantitative analysis ***(Johnston et al., 1977).***

3. Spectrum analysis:

Graphic display of the entire range of frequencies and amplitudes of the Doppler spectrum may be carried out with a sound spectrum analyser using either the off line technique or real time technique.

In offline technique, the signal is recorded on magnetic tracks to be analysed and played back later through variable frequency filter. Real time analyser may use different methods of analysis that include fast fournier analysis, time compression frequency analysis and multifilter analysis. Real time display of the Doppler waveform is desirable since it speeds up the examination of the patient and permits the operator to position the probe in an optimum position to obtain an artifact free signal ***(Giddens and Kittney, 1985).***

It is possible to analyze either the instantaneous maximum velocity waveform or the instantaneous mean velocity waveform. the former is preferable for the following resons:

1. It is readily identified on recordings made by a frequency analyzer.

2. It is easier to obtain from the practical point of view.

3. It does not assume that the entire vessle cross section has been insonated with the ultrasound beam.

4. It does not presuppose that attenuation of the ultrasound by the artery is negligable. ***(Johnston and Kasam, 1985).***

The normal spectra reveal pulsatile wave forms with most of the Doppler signals amplitudes present along the upper border of velocity waveform.

The resultant clean area beneath peak systole 'the window' is relatively smaller in continuosis wave Doppler then the corresponding one in pulsed Doppler because of the sampling effect. ***(Jehnston and Kassam, 1985).***

Quantification of Impedence:

Impedence is the total resistance to flow from all factors. It is inversely proportional to the flow when all other factors are constant.

The impedence of the receiving circulation can be quantified by means of the waveform of the blood vessel supplying that circulation. A number of different indices have been used to quantitate impedence. One advantage of these indices is that the angular correction and vessel size cancel each other out and thus it is not needed to be known. Another advantage is that it is a ratio and hence it does not matter whether velocities or kilohertz shifts are used in their calculation ***(Taylor and Holland, 1990).***

The systolic/diastolic ratio or the A/B ratio where A is the peak systolic frequency and B is the end diastolic frequency, has been used widely in obstetric studies. The only disadvantage of this simple parameter is the fact that when diastolic flow is zero, the ratio becomes infinity.

Another index is the pourcelot (or resistive) index which is equal to peak systolic frequency (A) peak distolic frequency (B) / peak systolic frequency (A). This index has been used primarily in the evaluation of renal transplant and it has the advantage of never being equal to zero or infinity. The most sensitive one among these, indices, is the pulsatility index which is equal to A-B/mean. This is because it takes into account the mean velocity. These ratios are useful for displaying functional pathologic changes but they one relatively crude indices. For example the dramatically different signals in tumours and in normal parenchymal flow have the same resistive or pulsatility indices. This is because both the systolic and the distolic velocities one greatly increased so that the ratio between them is the same ***(Taylor and Holland, 1990).***

Effect of frequency of the probe "Frequency Selection":

Simple continuous wave Doppler devices usually have one inherited transmission frequency designed for specific application. Most of the devices used for clinical evaluation of peripheral vascular diseases have a frequency range between 5 and 10 MHz. Some devices permit selection or multiple transmission frequencies either with a selector switch or by means of exchange of Doppler probe.

Instruments with higher frequencies of transmission usually have smaller transmitting and receiving crystals, permitting greater lateral resolution. However because of the increased absorption and back scattering of the ultrasound at high frequencies the range at the depth of the penetration of such devices is limited. Doppler units operating at lower frequencies, have longer transmission and receiving crystals, thus the lateral resolution is decreased. Such devices are more suitable for examination of blood flow at greater tissue depths. ***(Nelson and Preterius, 1988).***

It is to be remembered that the greater the frequency of transmission used, the greater the Doppler shift expected. Thus it is advisable to use the greatest frequency possible for better interpretation ***(Nelson and Preterion, 1987).***

The effect of the angle:

The amplitude of the waveform produced by the Doppler velocitymeter depends on the angle between the ultrasound probe and the axis of the blood flow. As the probe angle is changed towards O', the amplitude of the wave increases, although the shape remains unchanged. The angle between the probe and the vessel should be as small as possible ($<60^o$) in order produce signals with large signal to noise ratio. Accurate velocity measurement requires a correction to be made for the angle effect. In order to produce an accurate correction, the anatomy of the vessel needs to be understood clearly. Tortous vessels constantly change direction making angle correction extremely difficult. ***(Johnston et al., 1977).***

Pulsed Doppler:

One of the limitations of the continuous wave Doppler is that when two vessels are insonated simultaneously, the signals from both appear superimposed in the output. Spatial separation is possible to be achieved by focussing the ultrasonic beam to allow the ultrasound to be directed towards one vessel while avoiding the other and by electronic method of selecting the Doppler shifted signals from a single depth while rejecting signals from all other depths. the pulsed Doppler system was designed to accomplish this ***(Barnes et al., 1978).***

In pulsed Doppler the sound pulse is transmitted and received by a single transducer. The time delay between the pulse and the echo depends on the velocity of the sound and the depth of the reflector. Each centimeter in the depth is displayed as 13u sec.

Thus to receive an echo from a depth of 3 cm., it must accept signals coming 40u sec. after starting transmission and ignore the others. To accept signals from a 1mm slice of tissue at that depth it should allow the signals for 1.3 u sec. after waiting 40 u sec. following starting transmission ***(Beach and Strondness, 1985).***