Editorial

DOPPLER ULTRASOUND

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In 1843, Christian Doppler, a physicist, described an effect which explained a change in the perceived frequency of sound emitted by a moving source. The same was later acknowledged as the 'Doppler effect'. The principle is extended to the field of ultrasound imaging wherein the insonation frequency of the transducer undergoes a change when reflected by moving objects, which is perceived by the sonologist in an audio mode. The formula governing the 'Doppler effect' is as under:-

$$\bullet v = \frac{2 \bullet s}{V} \cos \bullet$$

$\bullet v$ = frequency change (Doppler shift in Hz)

$\bullet$ = frequency of insonation beam (Hz)

s = Velocity of blood

V = Velocity of sound (1540 ms^{-1} in body tissues)

Current applications of Doppler ultrasound are in assessment of arterial and venous systems and cardiology. System wise, they can be summarised as follows :

1. Peripheral vascular system - Arteries and veins of the extremities
2. Central arteries / veins - Abdominal aorta, IVC, mesenteric vessels
3. Cerebrovascular system - Carotids, Jugular, Vertebral arteries, transcranial for middle and anterior Cerebral arteries.
4. Cardiology
5. Obstetrics and Gynaecology - IUGR, Uterine arteries, Ovarian torsion
6. Renovascular hypertension
7. Male infertility / erectile dysfunction, testicular torsion
8. Tumours, AV malformations.

There are five methods of imaging by employing Doppler principle :

(a) Continuous wave Doppler

(b) Pulsed wave Doppler

(c) Colour Doppler

(d) Power Doppler

(e) Spectral Doppler or Duplex scanning

(a) **Continuous wave Doppler (CW)** : This employs two piezoelectric crystals, both contained in a single head. One crystal transmits a continuous sonic signal at a known frequency (3-8 MHz). The other crystal receives the returning echoes and records their frequency. The frequency of initial signal is automatically subtracted from the returning signal. The difference 'Doppler shift' usually falls within the audible range. It is employed in detection of blood flow but does not give information of depth, direction and velocity of flow.

(b) **Pulsed wave Doppler (PW)** : This has provided the means of detecting the depth at which a returning signal has originated. The depth can be positioned at any point along the axis of the ultrasound beam. Detection of such mobile structures requires three basic technical parameters :

(i) High pulse repetition frequency - i.e. the difference between successive bursts of incident ultrasound beam

(ii) Using an optimum transducer frequency for that depth of body tissue, ie low frequency for deeper structures and vice versa

(iii) Use of correct insonation angle which should be less than 60°.

Because PW ultrasound does not provide the information about the structure / site of origin of an echo, it is customarily combined with a B mode / 2-Dimensional mode imaging, which is then called duplex scanning.

(c) **Colour Doppler (CD)** : Also called colour flow imaging (CFI) or colour velocity imaging (CVI). The echo signals received along a series of locations in an ultrasound beam width by applied transmit-receive

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pulse signals are called pulse packets. With most instruments, ten or more pulse packets are used to produce an estimate of mean velocity of all reflectors along multiple beam lines in the beam width. This data is assigned colour by the machine and is superimposed on B mode data from stationary structures within the beam width. Brighter shades in colour conventionally depict faster flow. The direction is conventionally denoted by assigning red colour to flow direction towards the transducer and blue colour away from the transducer.

(d) **Power Doppler or Energy mode imaging** : Colour flow imaging displays scattered velocities relative to the interrogating ultrasound beam direction at positions throughout the scanned field. An alternative processing method, which ignores the velocity and simply estimates the strength/amplitude of the Doppler signal detected from each location, is termed Power or Energy mode imaging. The Energy mode image is continuous and hence not sensitive to relative flow direction. It does not give the absolute values of velocity but only gives the strength of the Doppler signal. Thus, the advantages of Power Doppler over Colour flow imaging are:-

(i) More sensitive to flow states

(ii) Angle effects are ignored unless the angle is close to 90°FD so as to reduce Doppler signal level below threshold detection.

(iii) Aliasing, ie inability to detect Doppler frequencies beyond a particular level from a given depth and on the set of operating conditions. This limitation is not applicable to Power Doppler imaging.

There are disadvantages also, which are :

(i) Values of velocity and the direction of blood flow cannot be assessed.

(ii) Because of more averaging of information at slower frame rates, slow moving soft tissue signals appear as flash artifacts.

(e) **Spectral Doppler** : This type of display is typically used in vascular flow imaging by Duplex scanning (B mode + Pulsed wave Doppler) where the Doppler signal is of a complex nature in a given sampled volume of blood flow. In other words, each of the velocities sampled in the beam will have different phase and amplitude, thus the final character of the sampled signal will have contributions from each of these velocities. Thus, analysis of the entire spectrum helps in assessing the characteristics of vascular flow. These are further categorised into peak systolic and diastolic velocities, systolic / diastolic ratio, resistive index, pulsatility index, acceleration time, acceleration index and volume flow. Application of sets of these indices is paramount in detection of stenosis, its degree and the related flow abnormalities.

Thus, Doppler ultrasound applications form an important imaging tool today in a variety of clinical conditions. However, it does have limitations also. As for any ultrasound study, fat, flatus, faeces, motion (respiratory, peristaltic, cardiac or restless patient) cause hindrance to image quality. Secondly, changes in flow pattern occur proximal or distal to stenosis of a vessel only if the degree of stenosis is significant. Thirdly, multiple level stenoses / obstructions result in obscure patterns of flow. Fourthly, the flow patterns are subject to individual variations as also to other physical / physiological factors, thus making the diagnosis that much more difficult. In view of all these limitations, the learning curve is also flat and long before adequate degree of proficiency is achieved.

In conclusion, current Doppler ultrasound applications in clinical situations like Deep vein thombosis, Peripheral vascular disease (arterial), portal hypertension, Intra-uterine growth retardation, stroke etc need proper selection of cases on sound clinical judgement and the interpretation of results is guided by correlation of both.

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