

- Ultrasound employs high frequency sound waves, produced by piezo-electric crystal in a transducer.



Ultrasound Beam:

- Mechanical wave consisting of alternate compressions & Rarefaction
- During the compression, there is an increase in pressure at tissue.
- During rarefaction, there is decrease in pressure.
- For diagnostic imaging, ultrasound spectrum above 1 MHz is used.

USG Probes & Their Indications:

(A) Penul Probe:

- Least frequency probe
- Frequency is 1 to 2 MHz
- It is used for Transcranial doppler / transcranial colour duplex imaging.



(B) Convex / Curvilinear Probe:

- Most commonly used probe overall
- Frequency 3.5 to 5 MHz



- It is used routinely for all abdomen & pelvis ultrasound / obstetric ultrasound / Obstetric doppler.

(C) Linear Probe:

- Surface of probe is linear or flat
- Frequency = 7.5 - 12 MHz
- It is used for small part imaging such as Neck, thyroid, eye, local swellings, joints, breast.
- Also used for peripheral vascular doppler.



(D) Endoluminal Probe:

- Linear / tubular probe
- Frequency = $> 10 \text{ Hz}$
- Used in -
 - (i) Transvaginal ultrasound
 - (ii) Transrectal ultrasound
 - (iii) Transesophageal echocardiography
 - (iv) Endoscopic ultrasound
 - (v) Endovascular ultrasound.



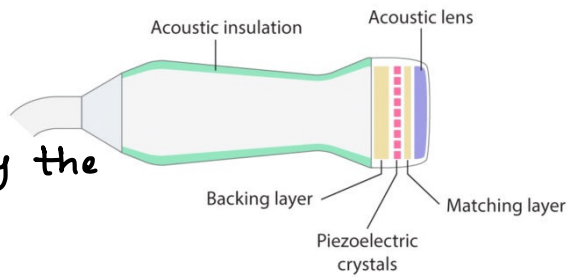
(E) UBM (Ultrasound biomicroscopy) probe:

- Highest frequency probe
- Frequency is 50 MHz
- Used for evaluation of eye.

USG probe :

The ultrasound transducer

The ultrasound transducer from the side and front.



- Wire brings in electric current & carries away the signal.
- At the tip, there are piezoelectric crystals (piezoceramics)
- Most commonly used crystal - **Lead Zirconate titanate**.

Reverse piezo electric effect :

Electric current to probe (probe with wire)



Pass through lead zirconate titanate crystals



Re alignment of Internal dipole structures within crystals.



Crystals begin to vibrate at a frequency of $>20,000 \text{ Hz}$



Mechanical waves (ultrasound waves) formed around it

Piezo electric effect :

Ultrasound beam reflected from patient's body



Hits lead zirconate titanate crystals



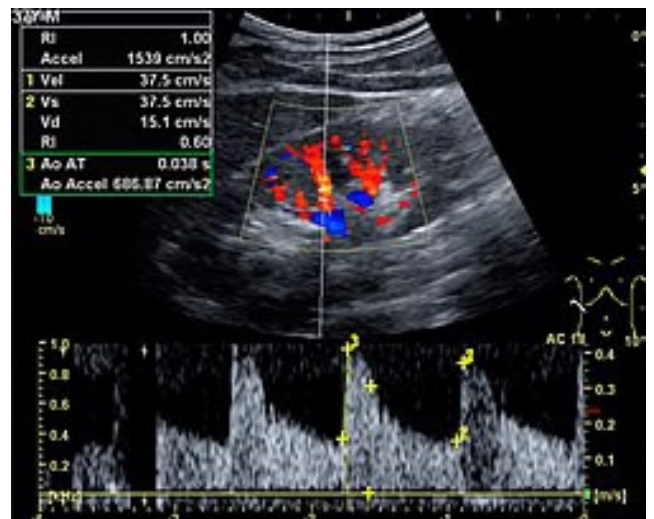
Crystal deformation occurs.

↓
Production of electric current in the
wire attached

- * Both piezo electric effect & Reverse piezo electric effect are used in medical diagnosis ultrasound.

Doppler Ultrasound

- Doppler ultrasound is a technique to examine moving structures in the body.
- Blood flow velocities are measured using the principle of a shift in reflected sound frequency produced from moving structures.
- It is utilized for :
 - (i) assessment of Cardiac chambers & heart valves.
 - (ii) arterial flow studies , esp. carotids & peripheral vascular disease.
 - (iii) Venous flow studies for detection of deep vein thrombosis.
 - (iv) Helps to detect direction / velocity of blood flow.



Doppler equation:

$$A \quad f_{Dop} = \frac{2 f_o v}{c} \times \cos \Theta$$

where:

f_{Dop} = Doppler shifted frequency

f_o = transmit frequency

v = flow velocity

c = speed of sound

$\cos \Theta$ = angle of insonation

B

$$v = \frac{c \times f_{Dop}}{2 f_o} \times \cos \Theta$$

where:

v = flow velocity

c = speed of sound

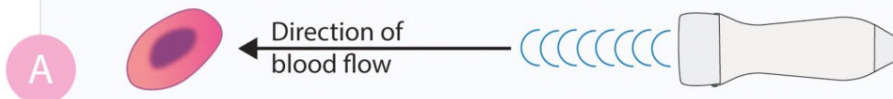
f_{Dop} = Doppler shifted frequency

f_o = transmit frequency

$\cos \Theta$ = angle of insonation

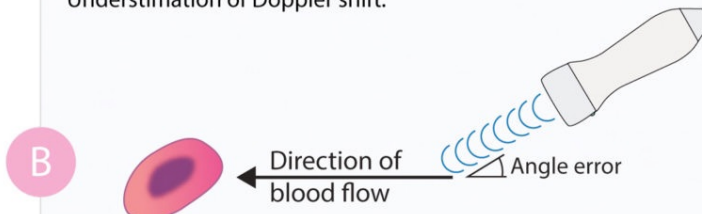
Angle of insonation

Accurate estimation of Doppler shift.



No angle error. Ultrasound beam is aligned perfectly with the direction of blood flow.

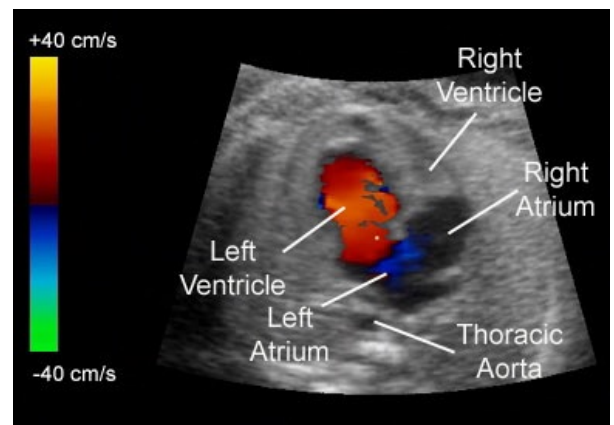
Underestimation of Doppler shift.



The angle of insonation is not parallel to the blood flow. The resulting angle error will lead to measurement error. All angle errors lead to underestimation of speed.

Colour doppler:

- Subjective method of doppler interpretation.
- Velocities recorded in a sample volume of pulse wave Doppler can be presented with a color.



- Blue colour implies Velocities (movement) away from the transducer.
- Red colour implies velocities (movement) towards transducer
- Brighter the colour, the higher the velocities.

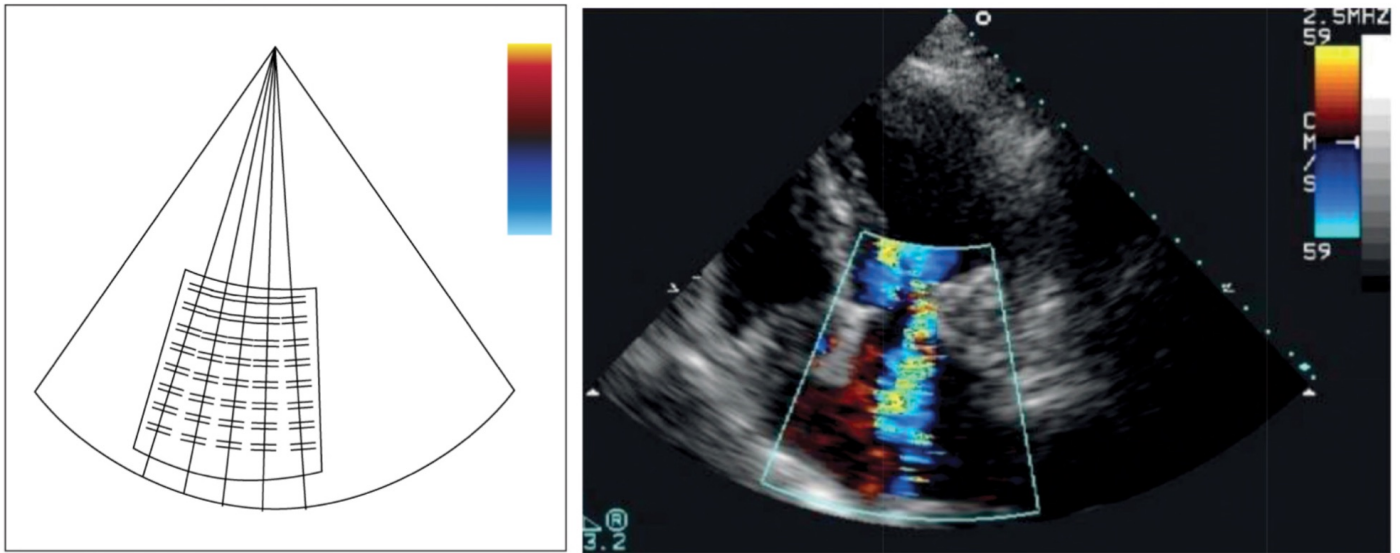


Figure 1. The image on the left shows many sample volumes within a Doppler sector. The picture on the right shows color Doppler located across the mitral valve and the left atrium.

- The main advantage of Colour Doppler :

- Rapid Visualization of Flows
- Velocities & Volume.

- Disadvantage :

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Low sensitivity
(Miss low velocity flow)

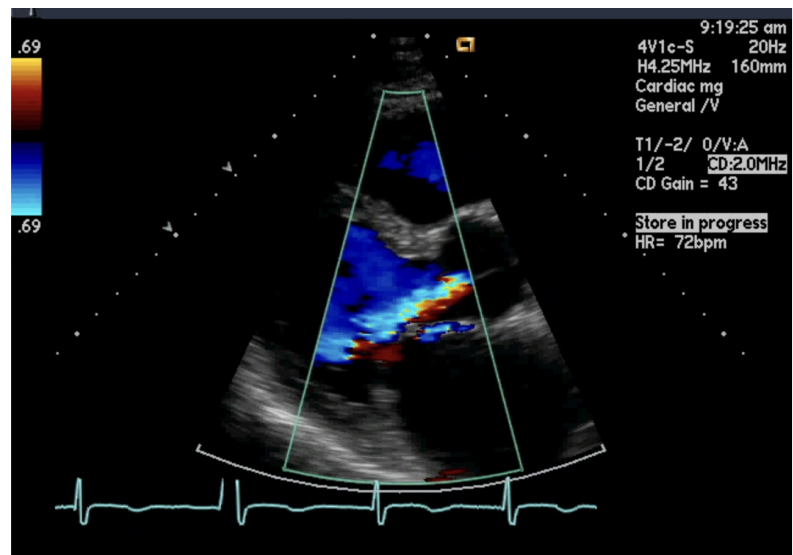
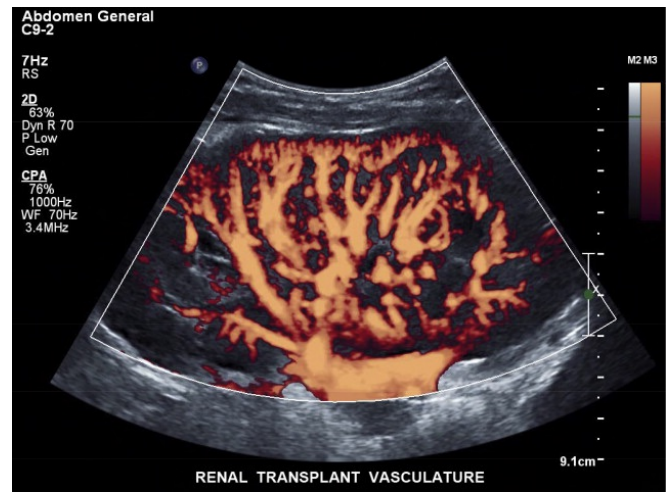


Figure 2. Color Doppler reveals the direction and extent of aortic valve regurgitation.

Power Doppler :

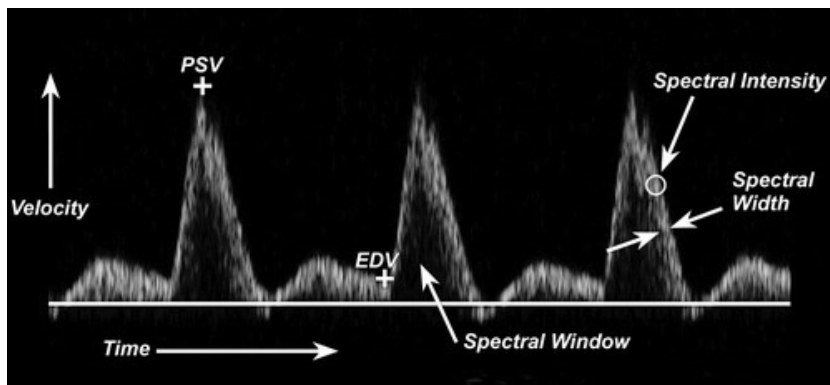
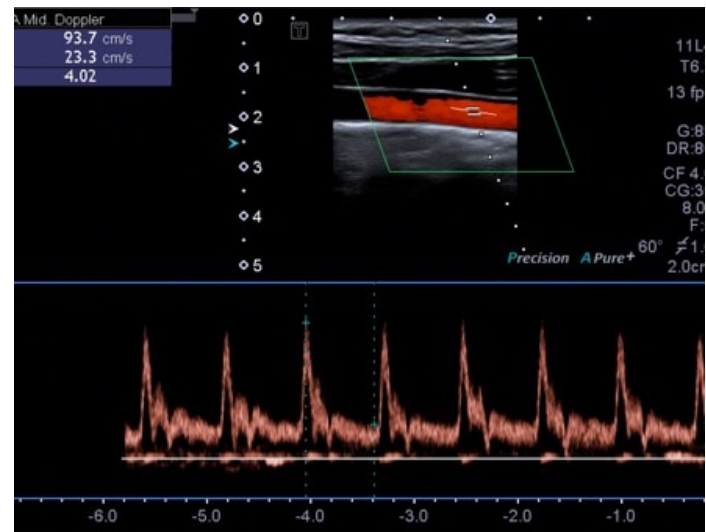
- High Sensitivity
- Can detect low Velocity flow
- Subjective method
- Single colour display

↓
Direction of flow is not shown



Spectral Doppler :

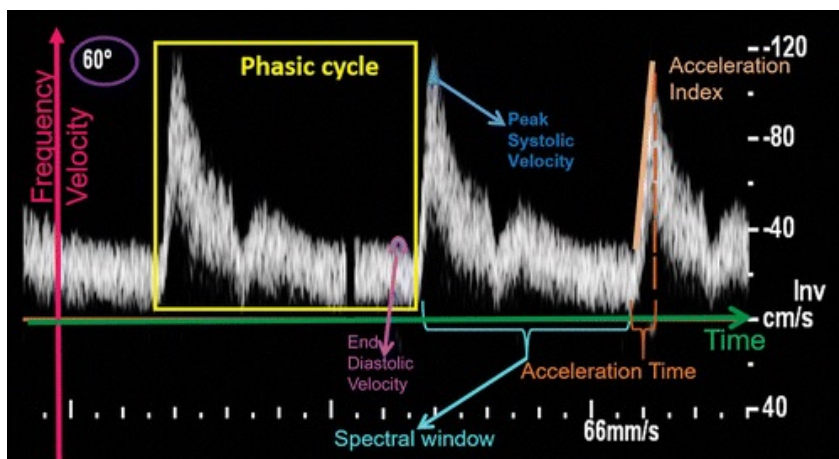
- Objective technique.
- Blood flow can be measured
- Velocity information can be known from frequency.



Highest peak = Peak Systolic Velocity (PSV)

lowest point = End Diastolic Velocity (EDV)

Area under curve = Blood flow volume.



Spectral Doppler

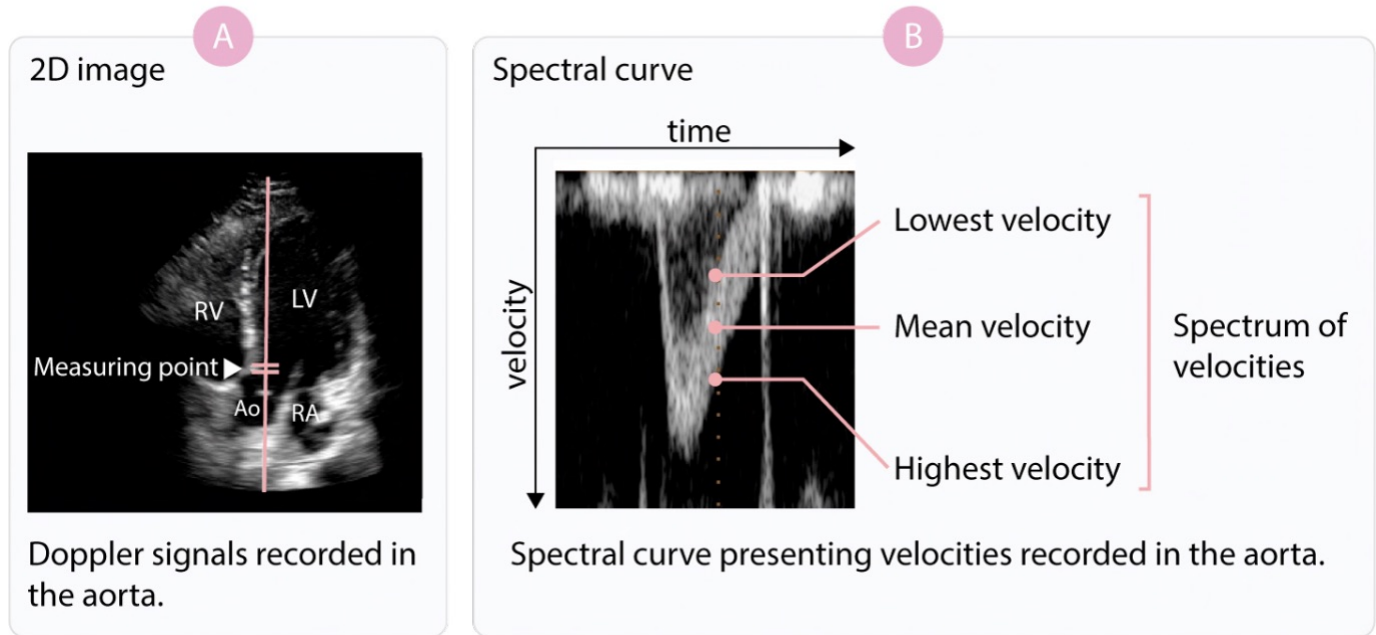


Figure . (A) Doppler recording in the left ventricular outflow tract (LVOT). Doppler signals are recorded in one point and (B) displays the resulting spectral Doppler, which shows all velocities recorded in the measuring point.

Biological Effects:

Type of effect	Result
Thermal	Increase in tissue extensibility Increase in blood flow Modulation of pain Mild inflammatory response Reduction in joint stiffness Reduction of muscle spasm
Non-thermal	Cavitation Acoustic microstreaming In combination may result in stimulation of fibroblast activity, increase in protein synthesis increased blood flow, tissue regeneration and bone healing



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