Basics of Doppler Ultrasound

Dr. W.H. KWOK
Department of Anesthesia and Intensive Care
The Chinese University of Hong Kong
Prince of Wales Hospital
Shatin
Hong Kong

Doppler Shift

- When ultrasound waves are reflected from a moving structure (e.g. red blood cell), the wavelength and frequency of the returning waves are shifted
- If the red blood cell is moving toward the transducer, the frequency increases
- If the red blood cell is moving away from the transducer, the frequency decreases

Doppler Equation

- $\Delta f = (2f_o V \cos\theta) / C$

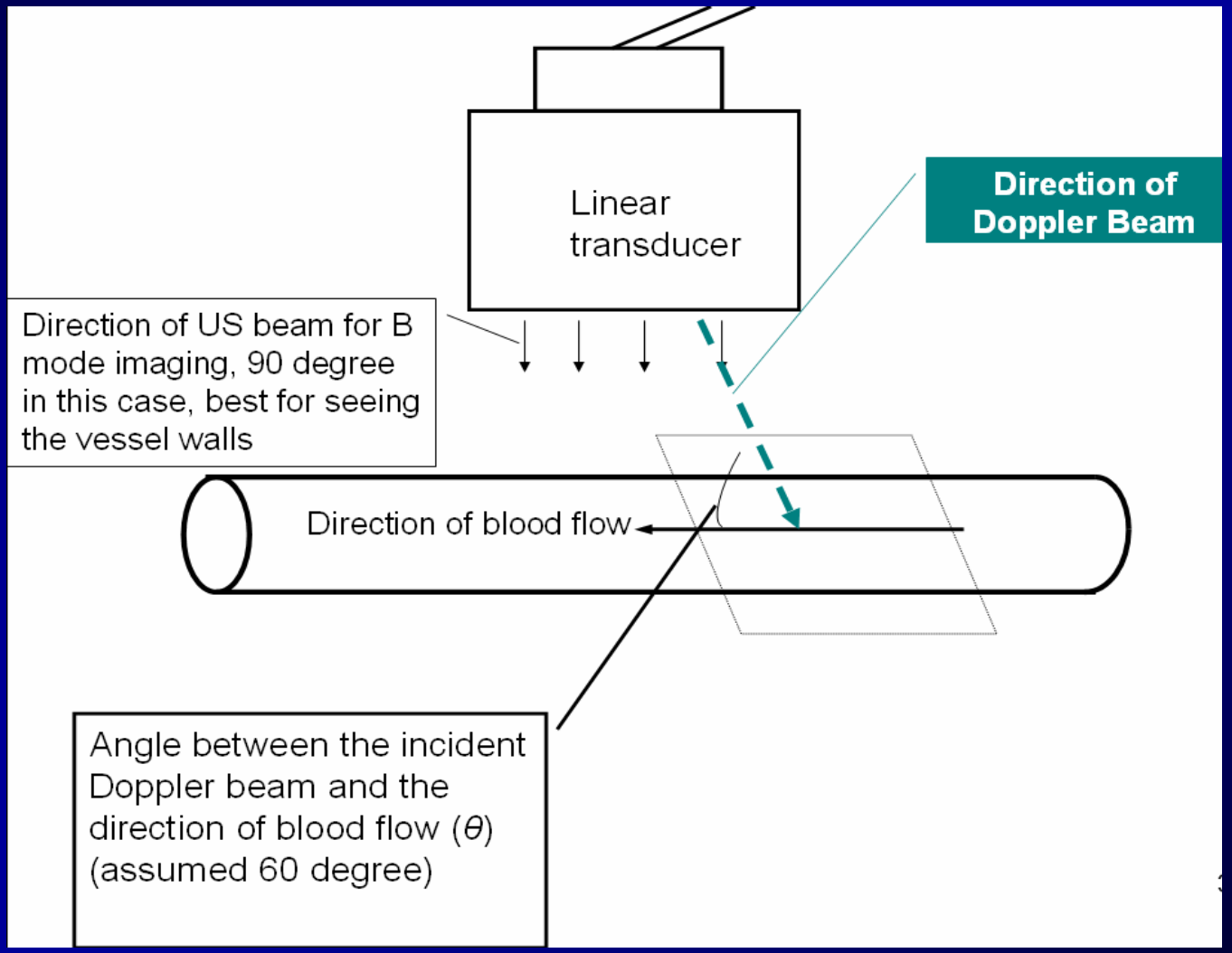
  - Δf: frequency shift
  - f_o: frequency of transmitted wave
  - V: velocity of the reflector
  - θ: angle between the incident wave and the direction of the movement of the reflector
  - C: velocity of sound in the medium

Importance of θ

- The frequency shift ($\triangle$f) is maximal if θ is zero degree (cos 0 = 1)
- The frequency shift ($\triangle$f) absent if θ is 90 degree (cos 90 = 0).

N.B. The best transducer orientation for the best B-mode imaging of a blood vessel wall is 90 degree to the vessel wall.

Doppler shift vs. B mode Imaging



If θ = 90 degree, cos θ = zero, then there is no doppler shift

Colour Doppler Imaging

- The Doppler shift information is obtained for a region of interest (ROI) within the B-mode image
- The average Doppler shift is displayed as colour information superimposed on the background gray scale B mode image
- Positive Doppler shift is assigned one colour and negative Doppler shift is assigned another
- The Magnitude of Doppler shift is represented by gradients of brightness of the assigned colour

- **Red** does not mean Artery
  - **Blue** does not mean Vein

Technique of Colour Doppler Imaging

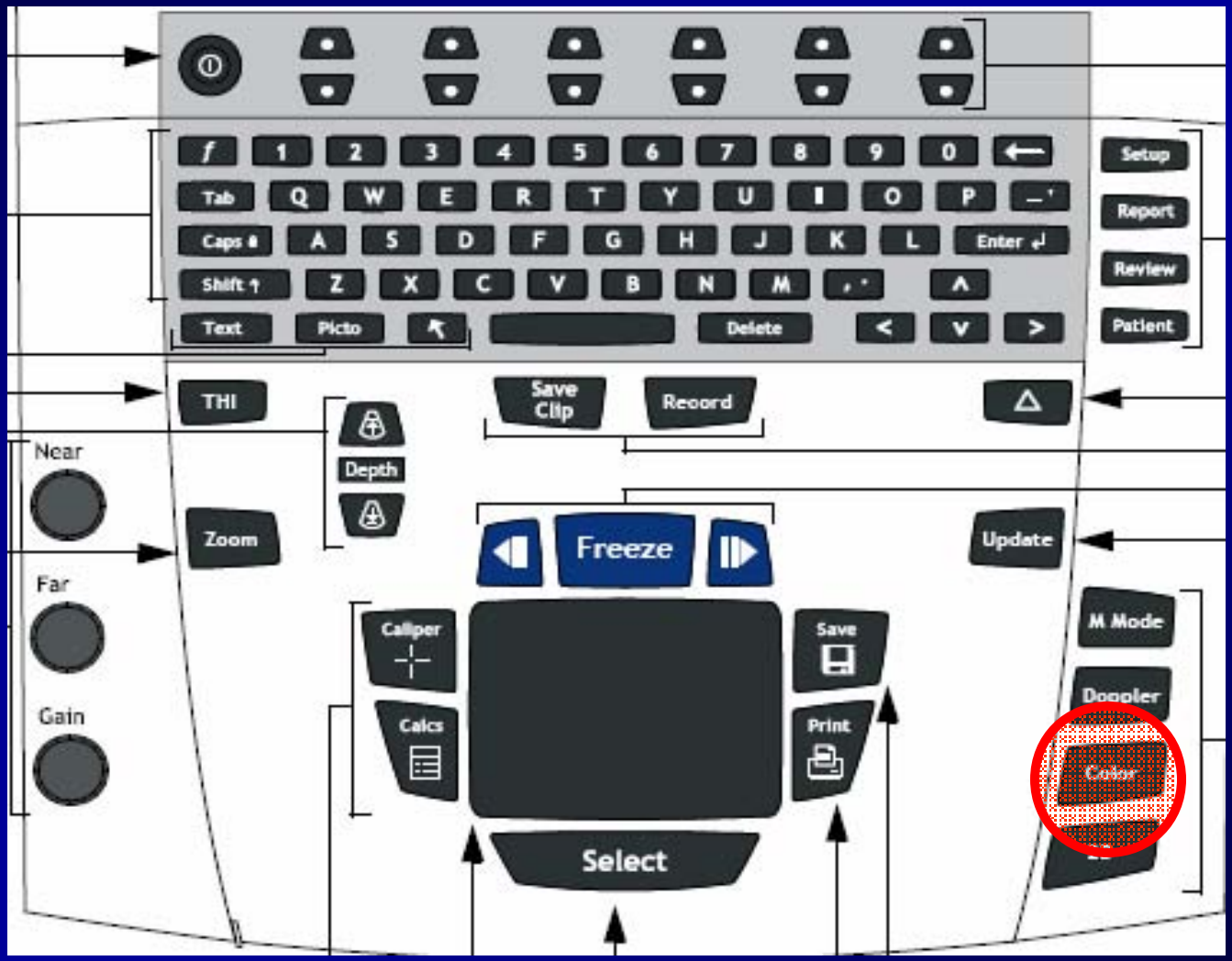
1. Optimize the B-mode (gray-scale) image
2. Press the Colour doppler mode knob
3. Position the Overlay Box over the region of interest
4. Adjust the steering of the box (direction of the Doppler beam)
5. Adjust the size of the box if necessary
6. Choose the appropriate velocities colour range
7. Press update to superimpose the colour information on the B-mode image
8. Interpret the colour carefully to identify the direction and pattern of blood flow.

Step 1: Optimize the B-mode (gray-scale) image

- Before the Colour Doppler is activated the B-mode (gray-scale) image should be optimized

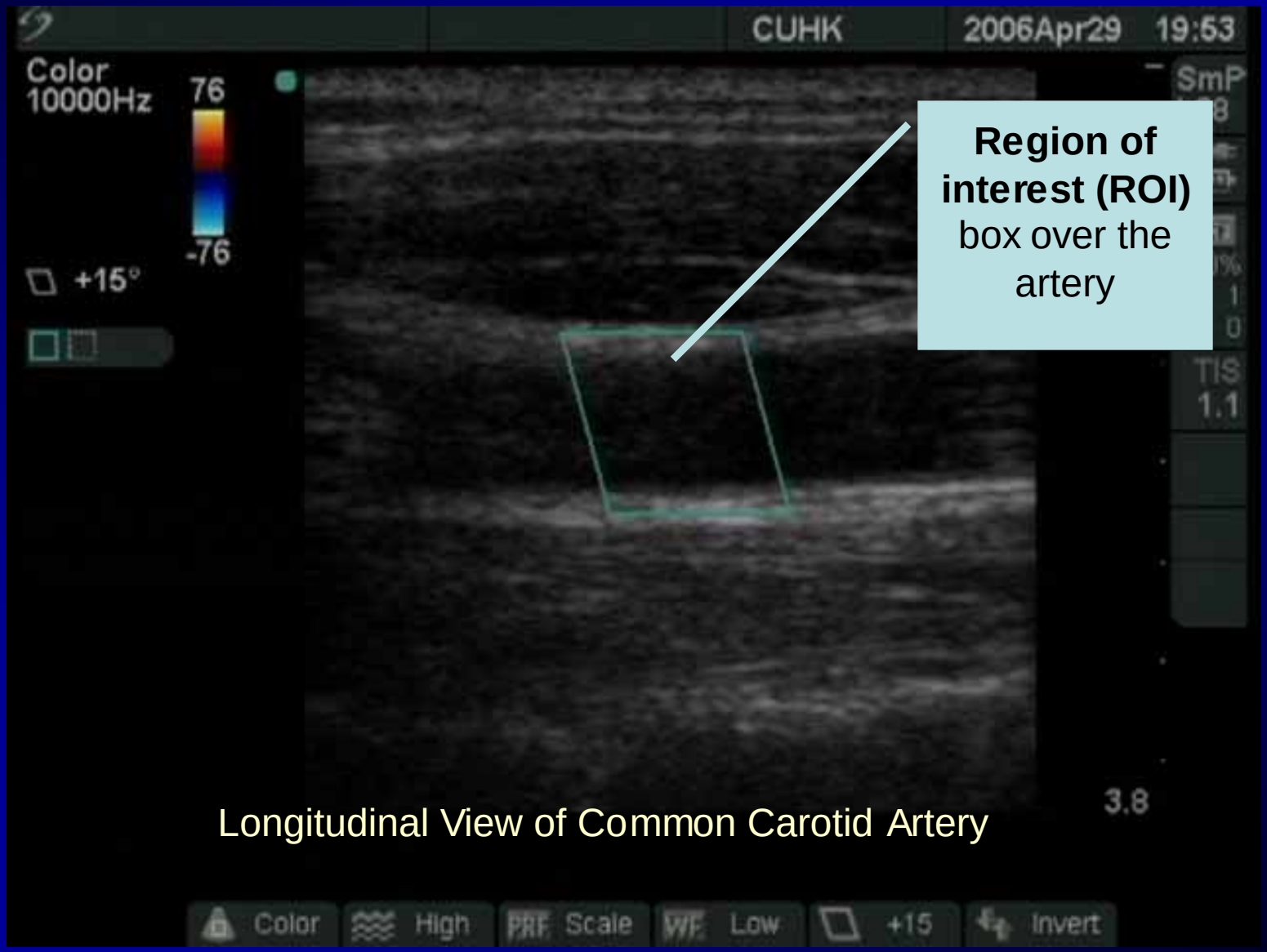
- Follow the Scaniing Routine: Select the correct probe, optimize the best preset setting, choose the correct frequency, adjust the depth of the field of view, using the correct gain, etc..)

Step 2: Activate the Colour Mode Knob

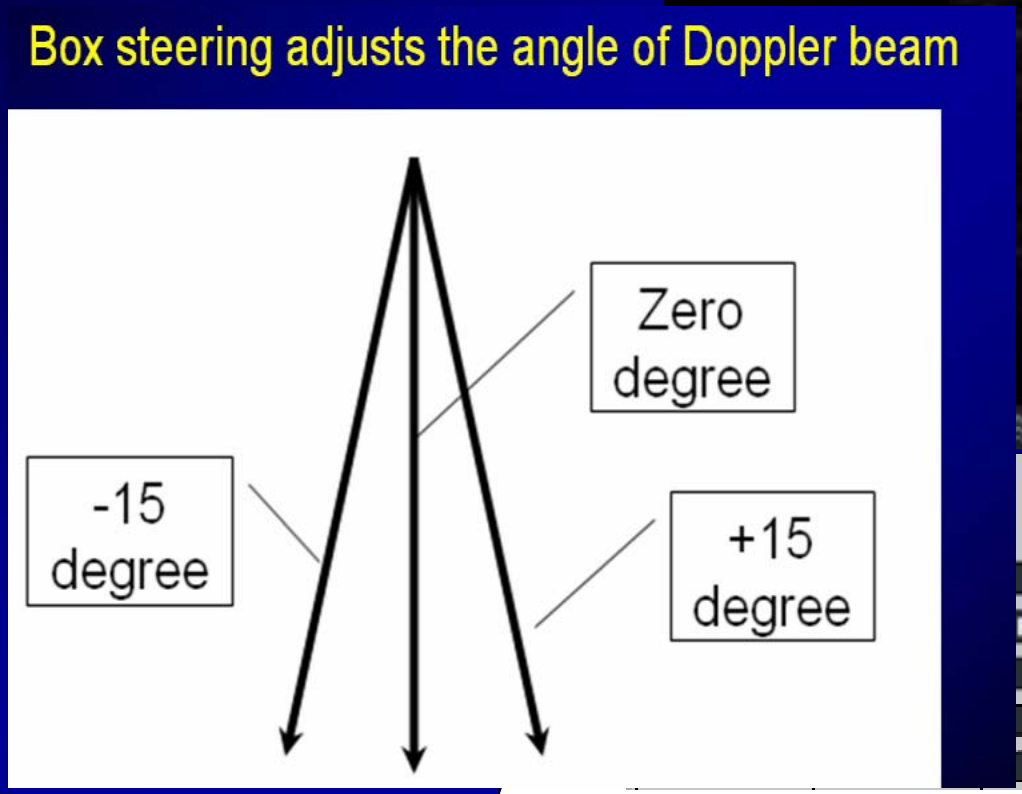


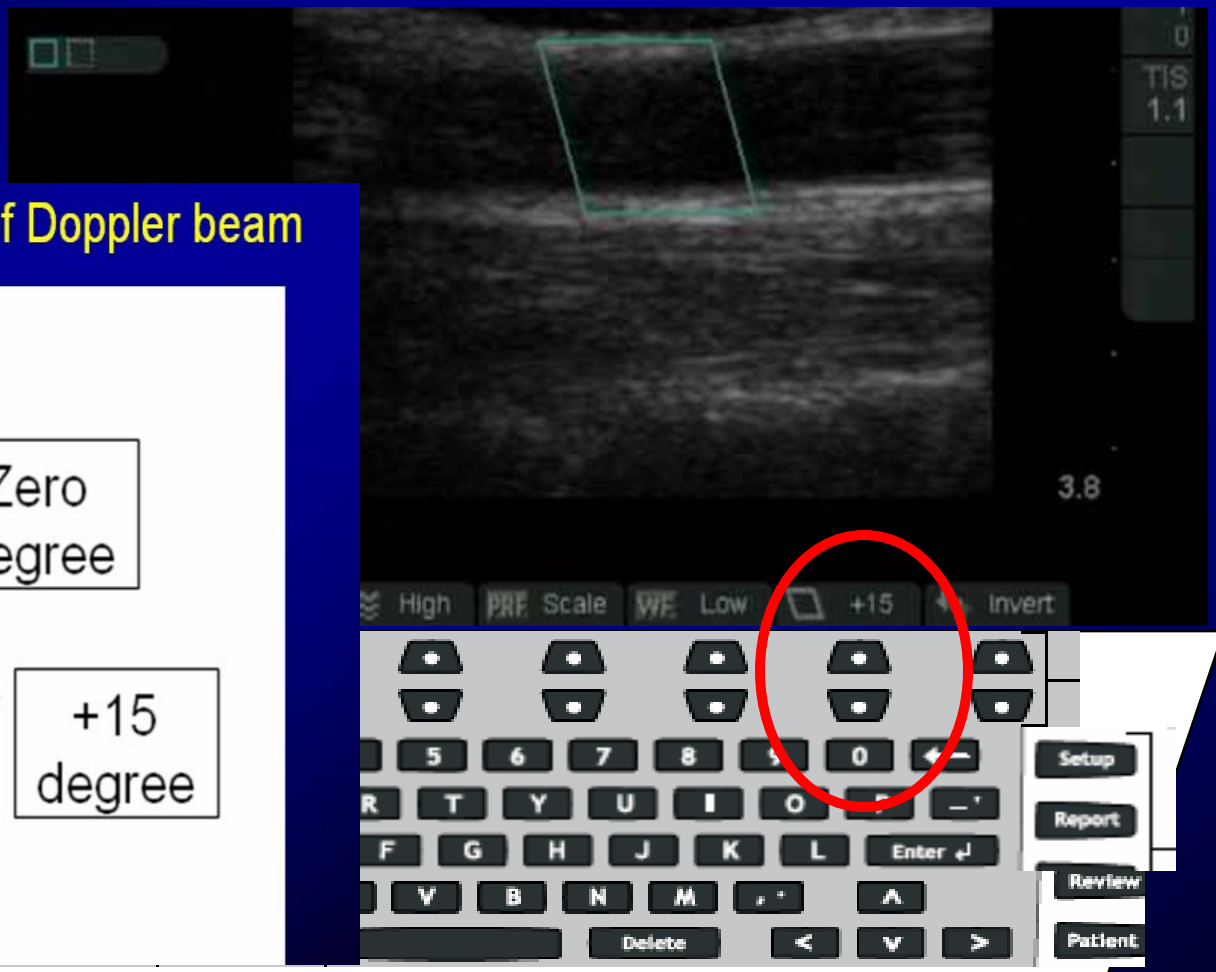
Panel of Sonosite's Micromaxx

Step 3: Select the Region of Interest (ROI)

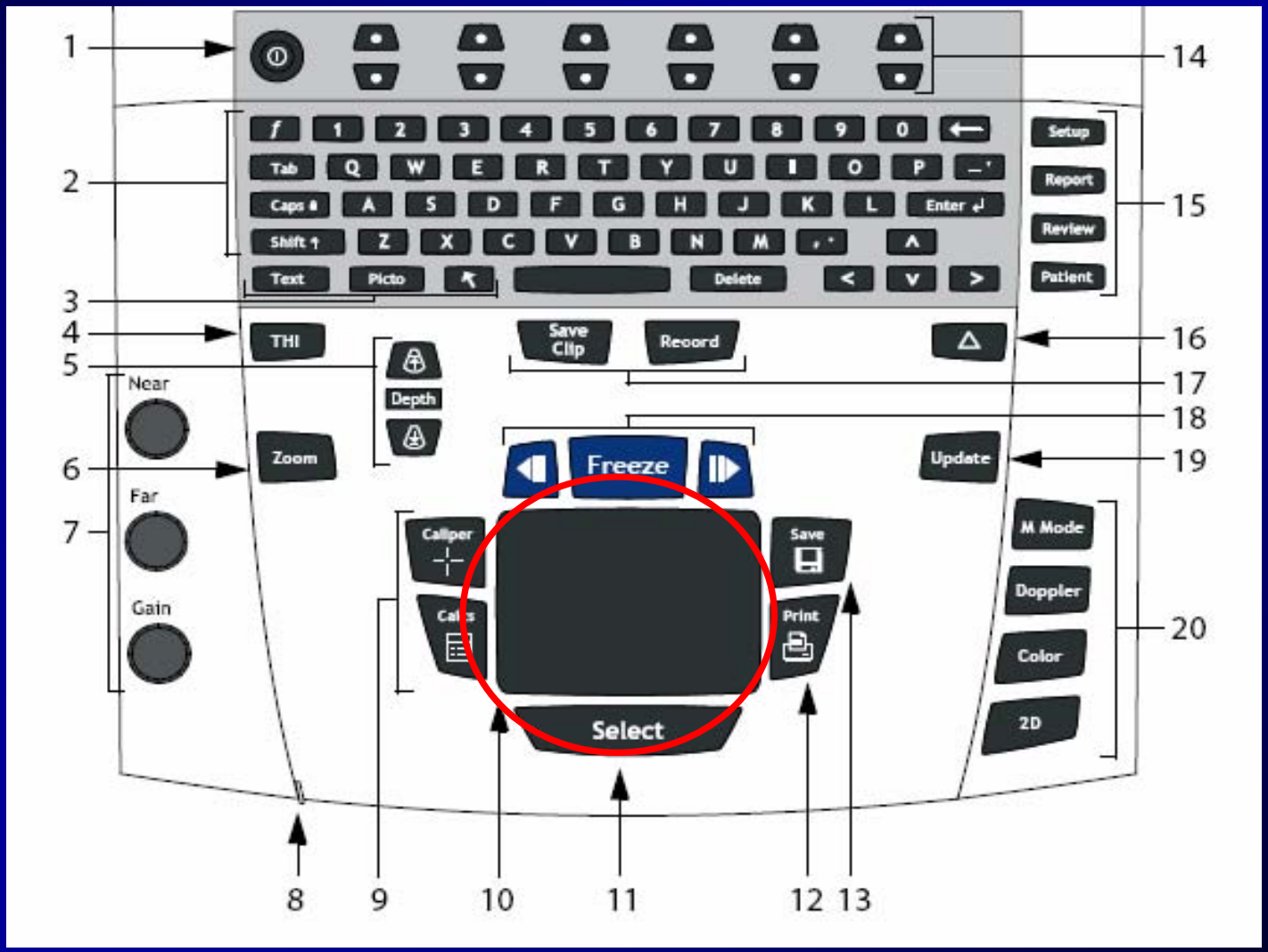


Step 4: Adjust the steering of the box (Direction of the Doppler beam)

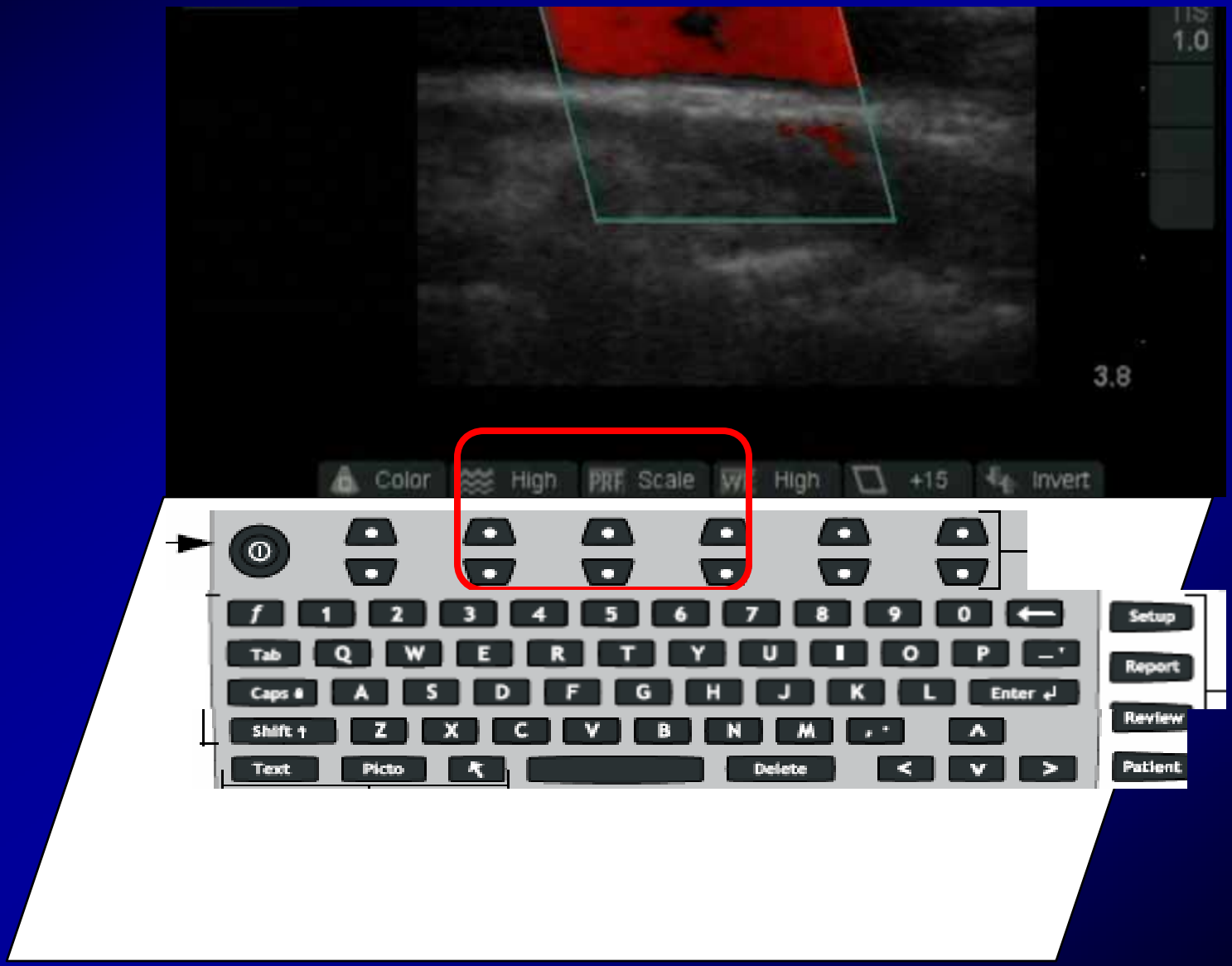




Step 5: Adjust the Size of the ROI box (Using the Select knob and Mouse pad)

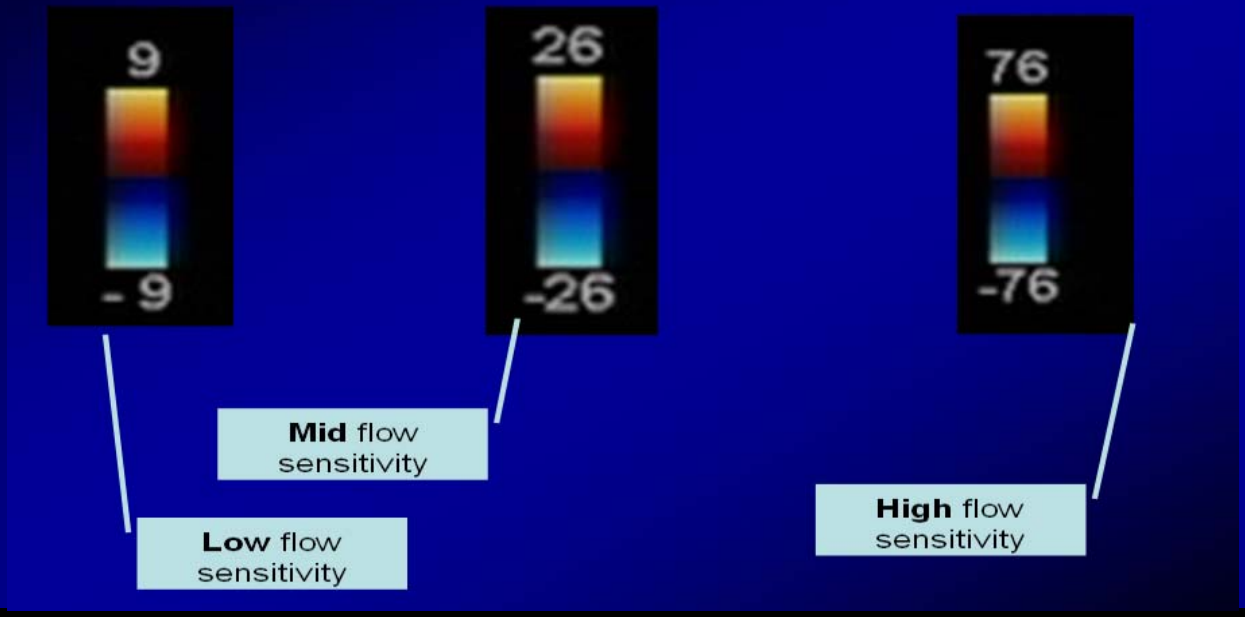


Step 6: Adjust the Colour velocity range



CUHK-PWH

Examples of velocity colour scale



Flow Sensitivity

Select the desired flow sensitivity from the on-screen menu.

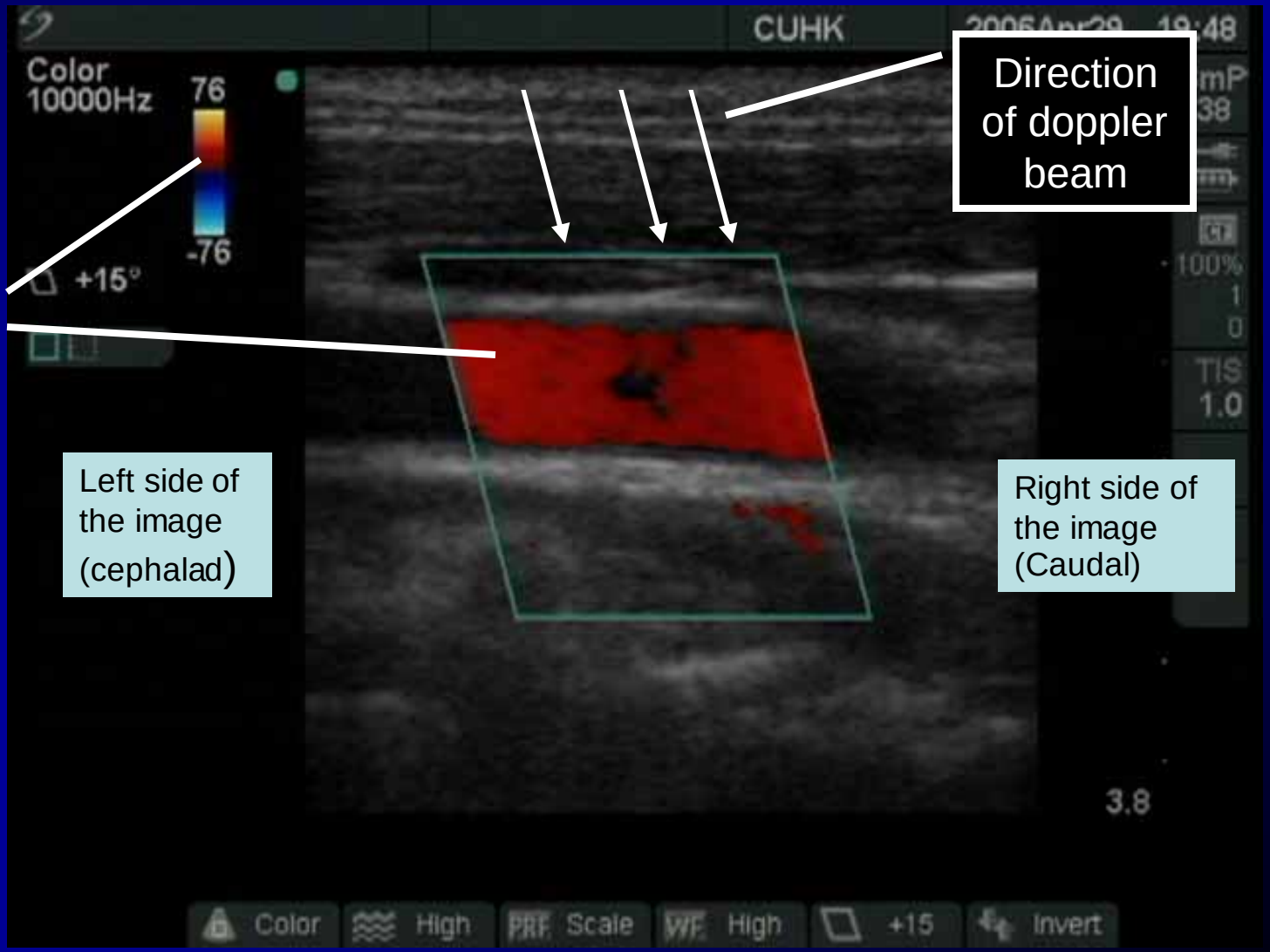
- Low optimizes the system for low flow states.
- Med optimizes the system for medium flow states.
- High optimizes the system for high flow states.

The current setting is displayed in the top left portion of the screen and in the on-screen menu.

PRF Scale (Color only)

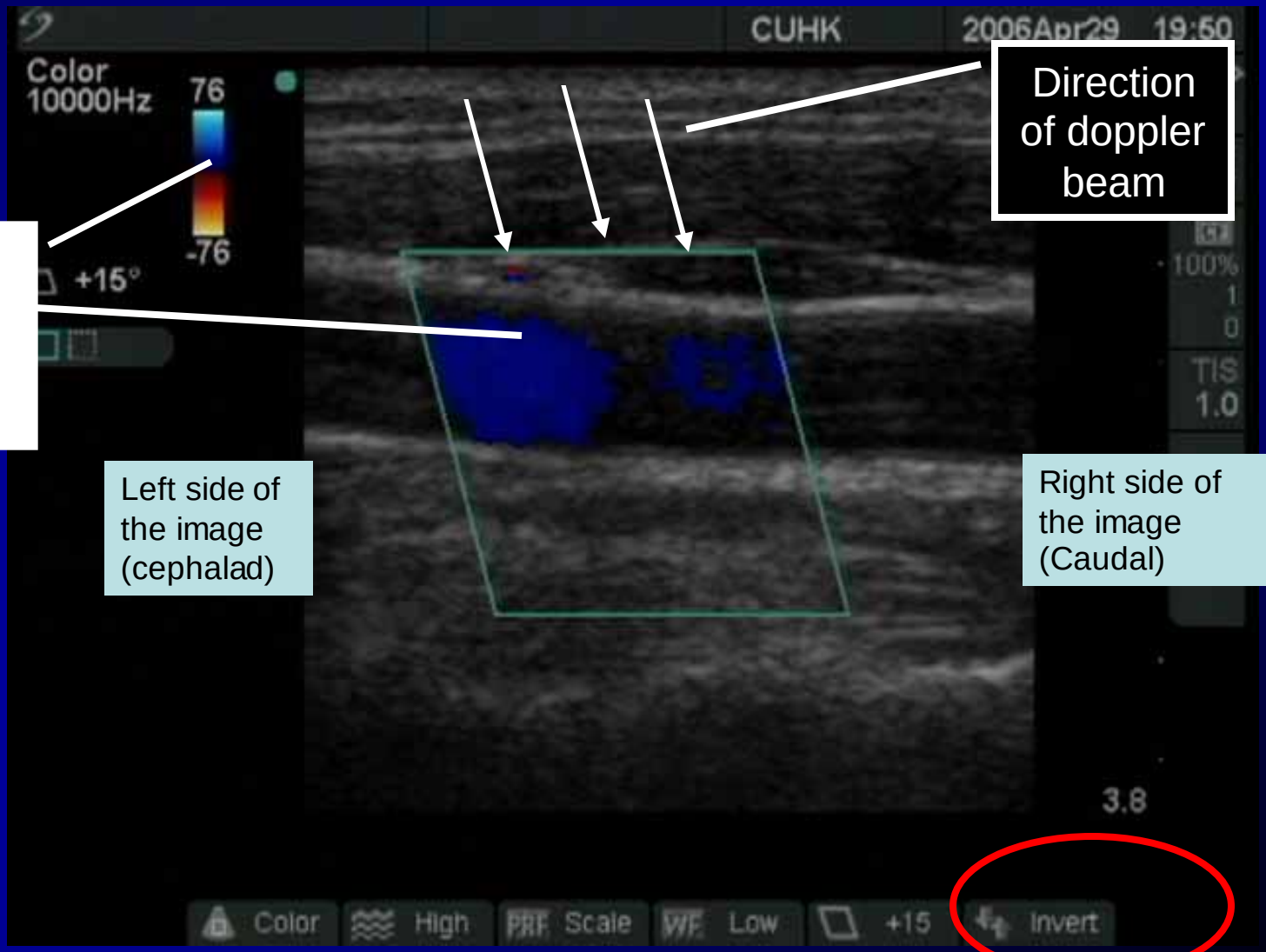
Select the desired pulse repetition frequency (PRF) setting from the on-screen menu.

Image 1: Colour Doppler of the Common Carotid artery



RED→ positive doppler shift → blood flow from right to left

Image 2: Colour Doppler of the Common Carotid artery with the colour scale inverted



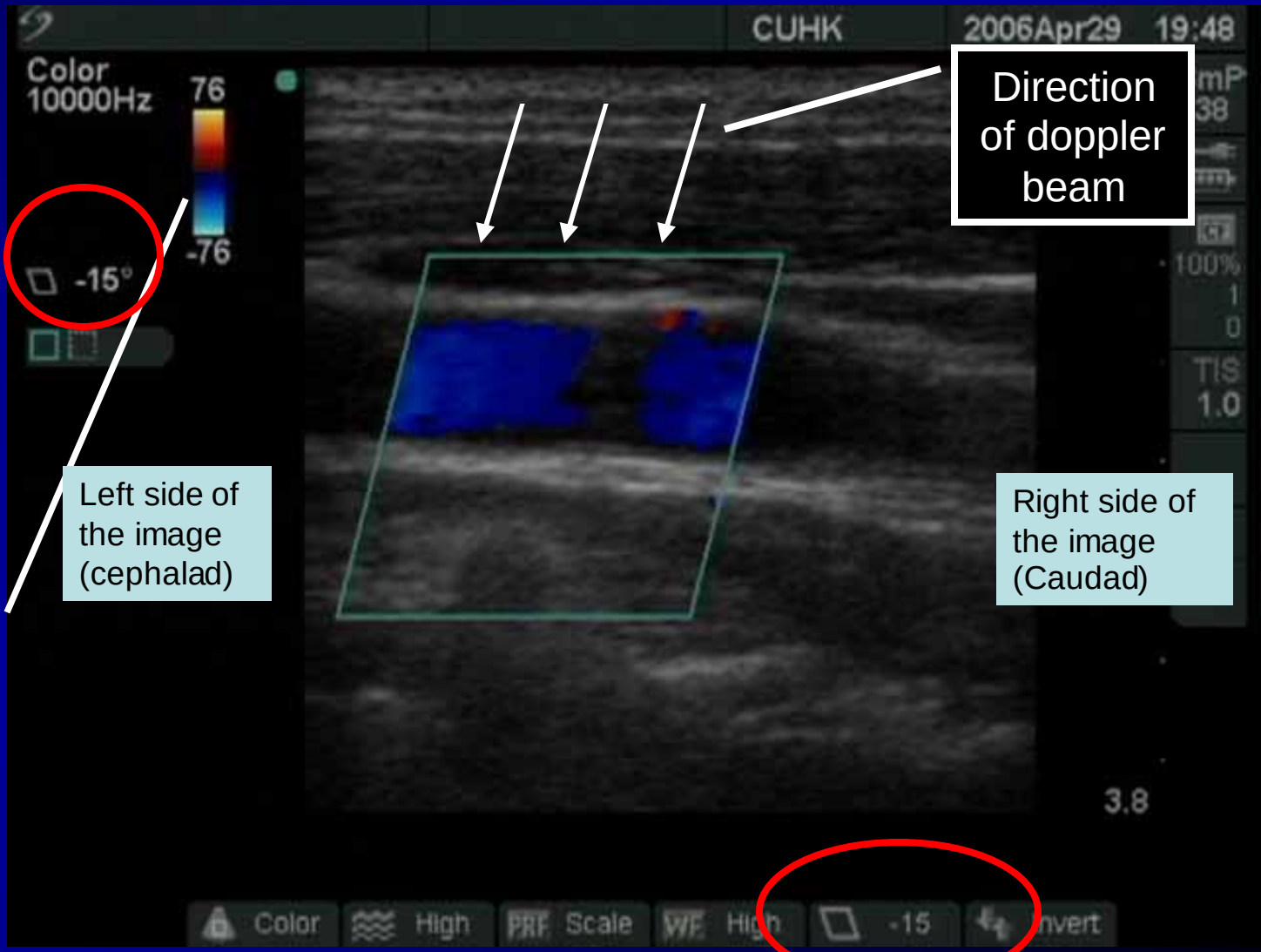
Direction of doppler beam

Blue→ positive doppler shift → blood flow from right to left

Left side of the image (cephalad)

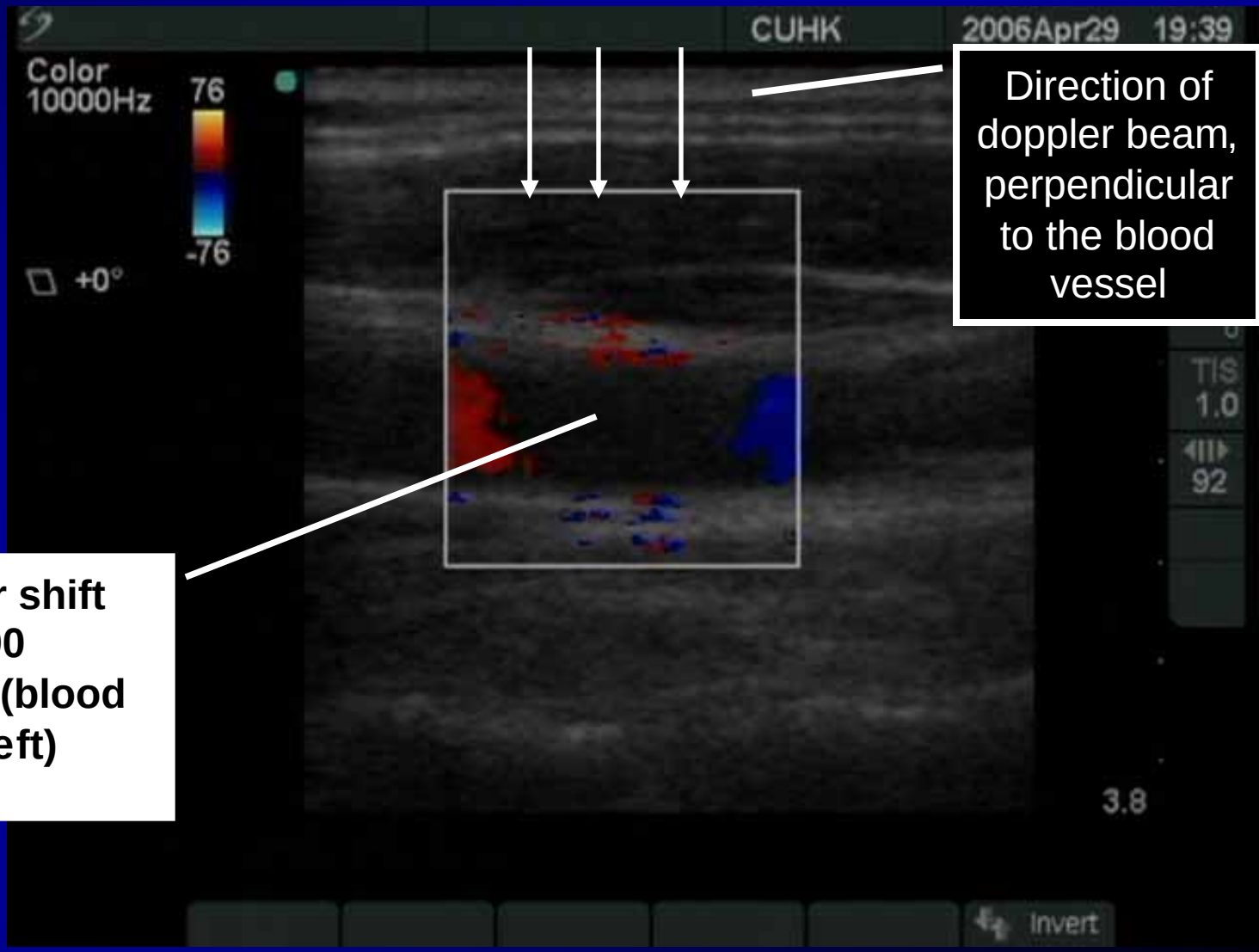
Right side of the image (Caudal)

Image 3: Colour Doppler of Common Carotid artery (different ROI box steering compared with Image 1 & 2)



Blue→ negative doppler shift → blood flow from right to left

Image 4: Colour Doppler of Common Carotid artery (zero degree box steering)



Direction of doppler beam, perpendicular to the blood vessel

Black → no doppler shift because the θ is 90 degree, cos 90 = 0 (blood flow from right to left)

Image 5: Aliasing with inappropriately low range of velocity scale on the colour bar

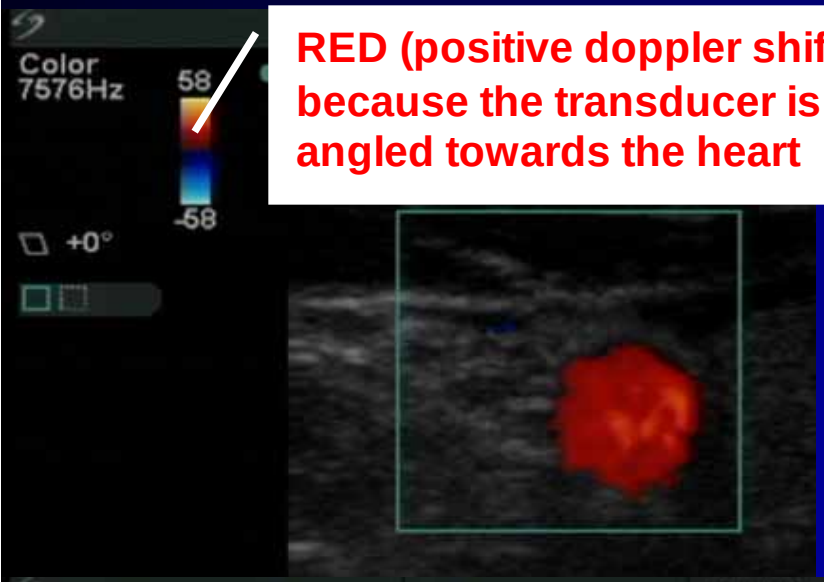
Blood flow is from right to left, but the colour signal "folds over" to the opposite direction. This is an aliasing artefact and does not represent true flow reversal. If flow reversal is true, the forward and reverse flow colours should be seperated by a black transitional area.

Aliasing & Velocity Colour Scale

- Velocity colour scale
  - ✓ The range of velocities that are assigned with colours
- If the measured flow velocity falls outside the selected scale, aliasing will occur
- This problem can be avoided by expanding the scale to allow the actual velocity to fall within the selected range of velocity

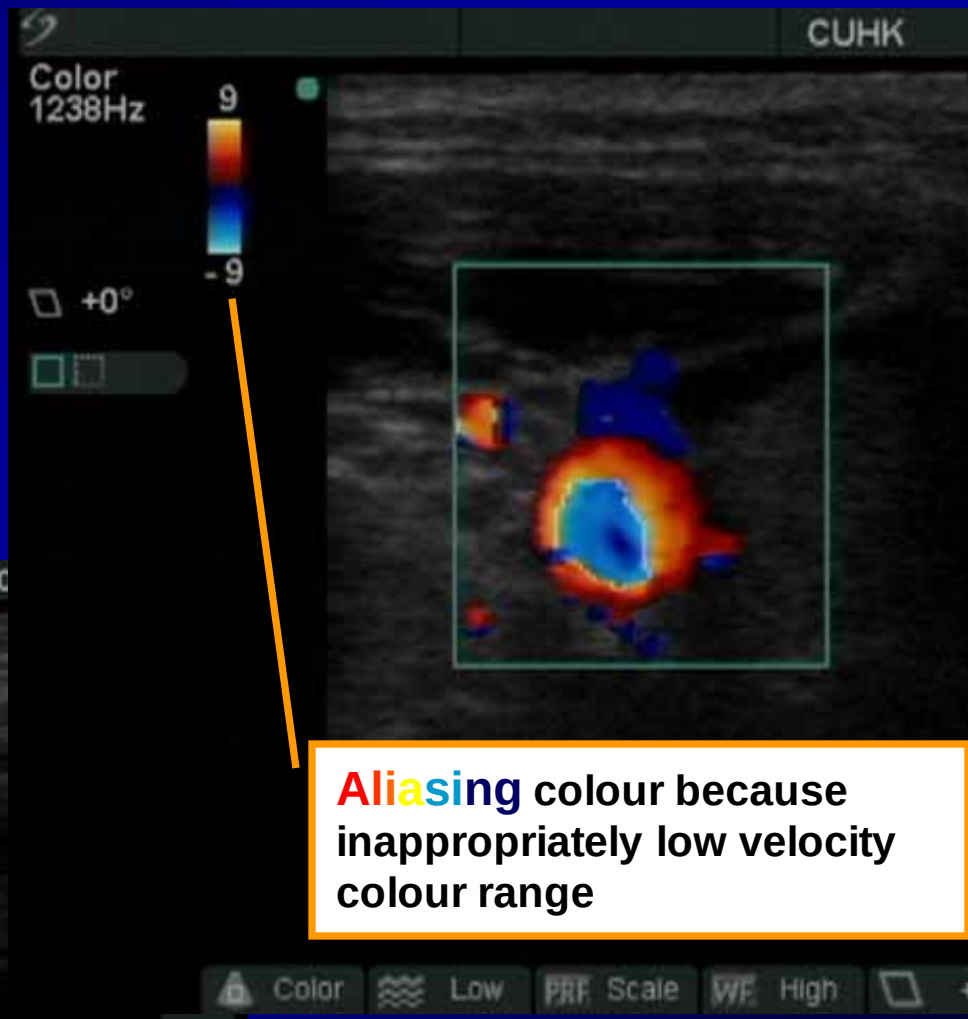
CUHK-PWH

Transverse view of common carotid artery



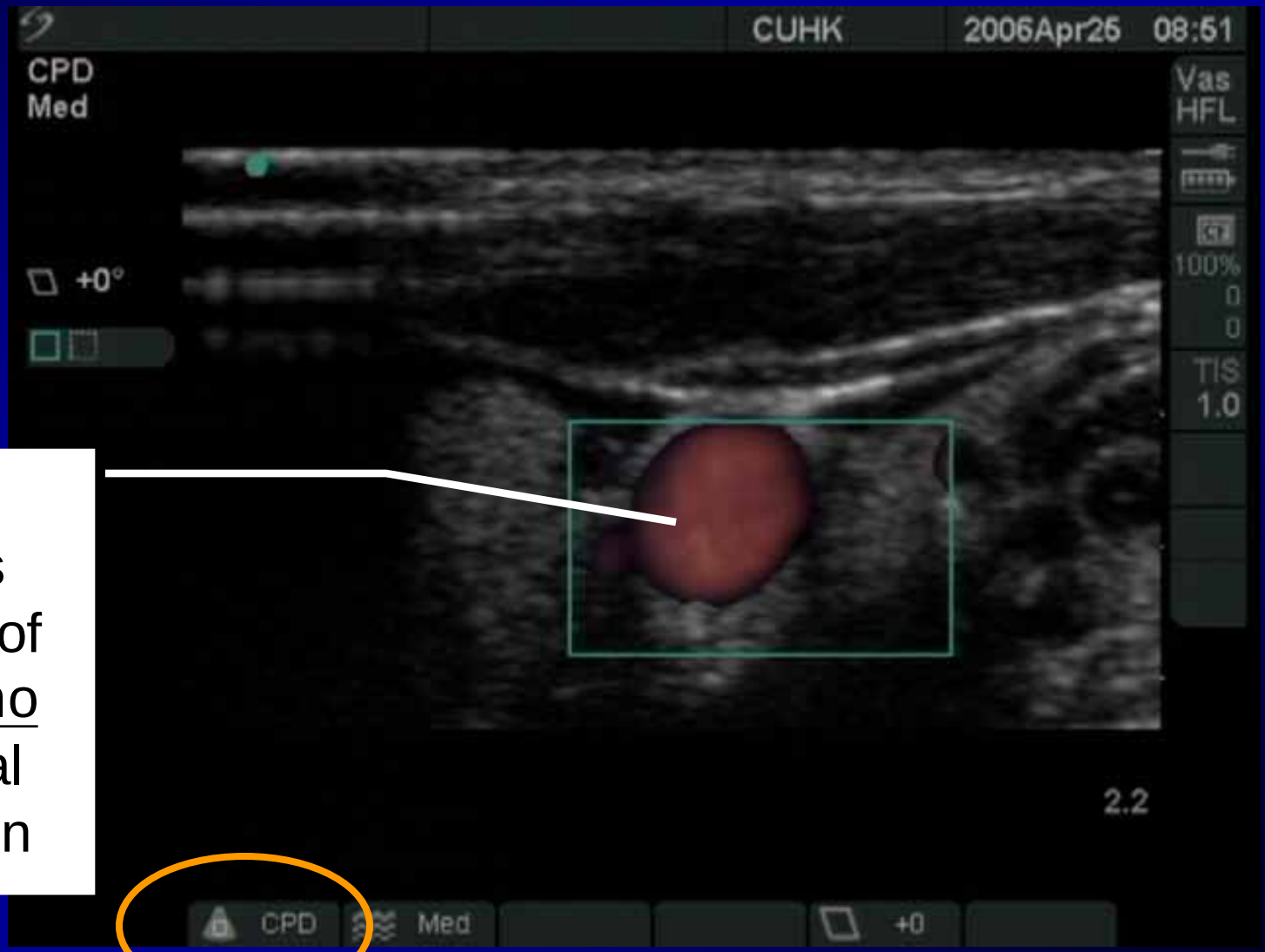
RED (positive doppler shift) because the transducer is angled towards the heart

Blue→ negative doppler shift → transducer is angled away from heart



Aliasing colour because inappropriately low velocity colour range

Image 9: Transverse View of Common Carotid Artery Using Colour Power Doppler (CPD)

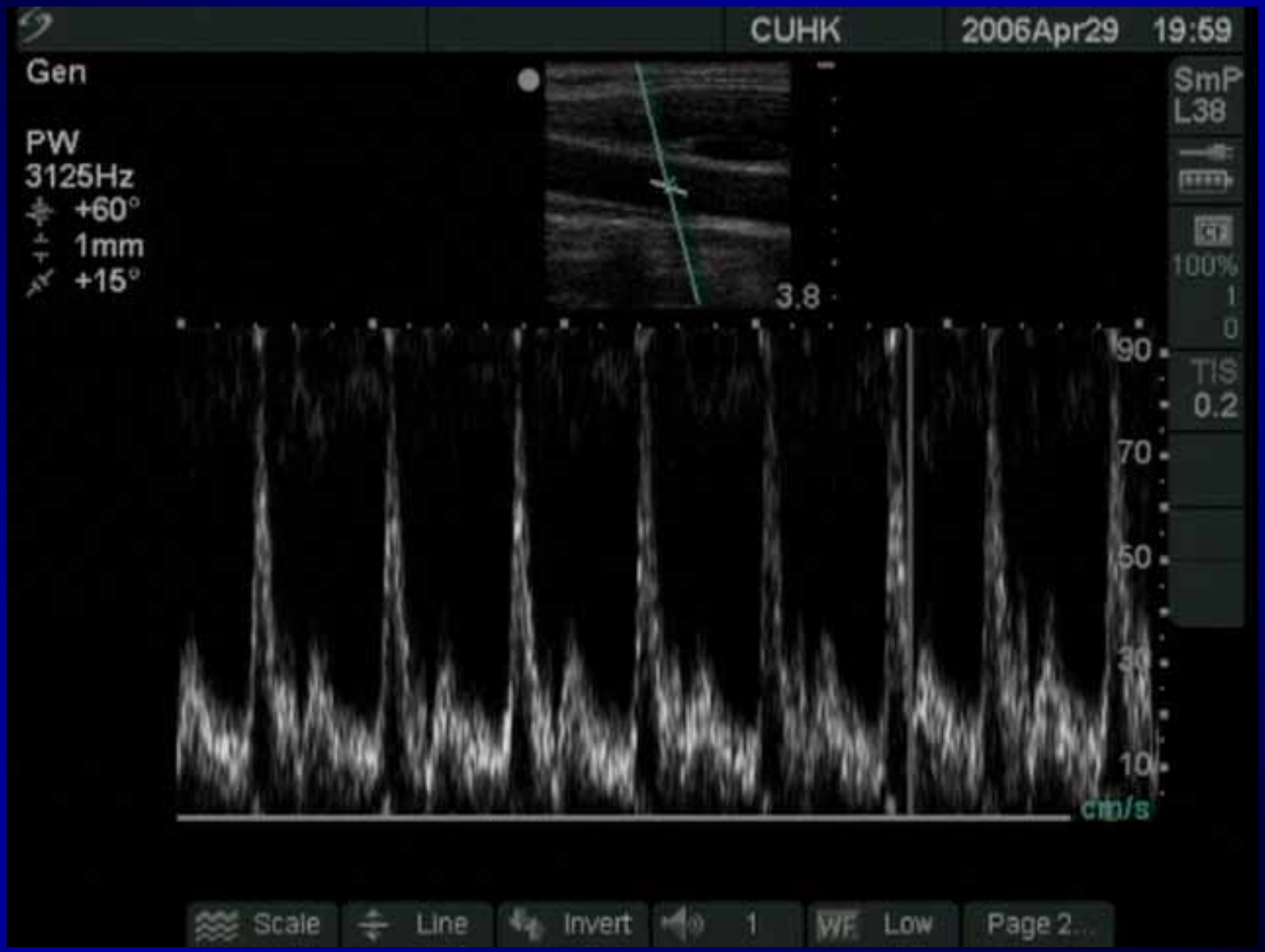


Colour indicates presence of flow, but no directional information

Pulse Doppler

- Provides quantitative data about flow velocities
- The operator can adjust the position and size of the sample volume from which the returned Doppler information is obtained
- The calculated velocities assumed the correct angle θ is used (60 degree in most case)
- If the real angle of insonation is not the same of the assumed angle correction used to solve the Doppler equation, errors in calculated velocities will occur

Pulse Doppler of the common carotid artery



Angle correction used (θ)

60 degree

Direction of pulse Doppler beam

Assumed direction of the blood vesel

Position of sample volume

Basics of Doppler Ultrasound

Supported by

Ultrasound Guided Regional Anesthesia Workshop

Department of Anesthesia and Intensive Care
The Chinese University of Hong Kong
Prince of Wales Hsopital
Shatin, Hong Kong

Web link: http://www.aic.cuhk.edu.hk/Ultrasound Workshop/