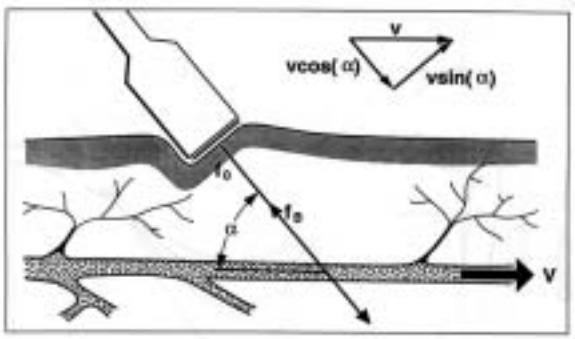
Principles of Color Doppler and Power Doppler ...邵耀華

The Doppler effects was first observed and formulated in 1842 by Austrian physicist Johann Christian Doppler (1805-1853). This phenomenon occurs when the source and the receiver are mowing relative to each other. If the sound source is moving toward the receiver, the receiver will obtain a sound wave at a higher frequency than the emitted wave. The frequency-increment is proportional to the magnitude of approaching velocity.

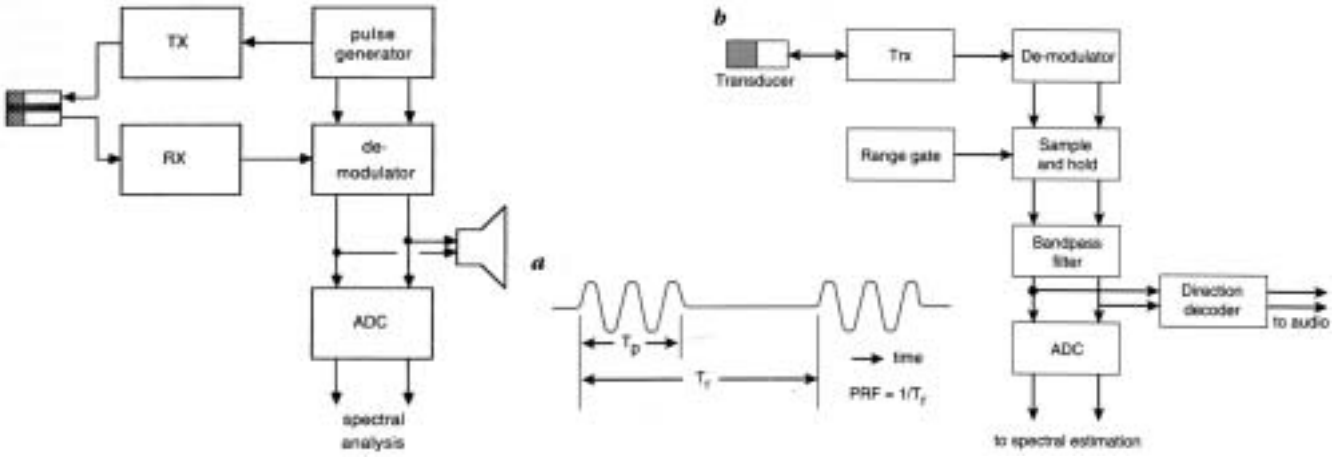
Doppler ultrasound provides a non-invasive measurement of blood flow in human body, the first attempt has been done by Satomura (1956) in the investigation of flow in the heart.



$$f_d = \frac{2\ V\cos\alpha}{C} f_o$$

Scattering of
Red Blood Cells

CW Doppler System vs. PW Doppler System

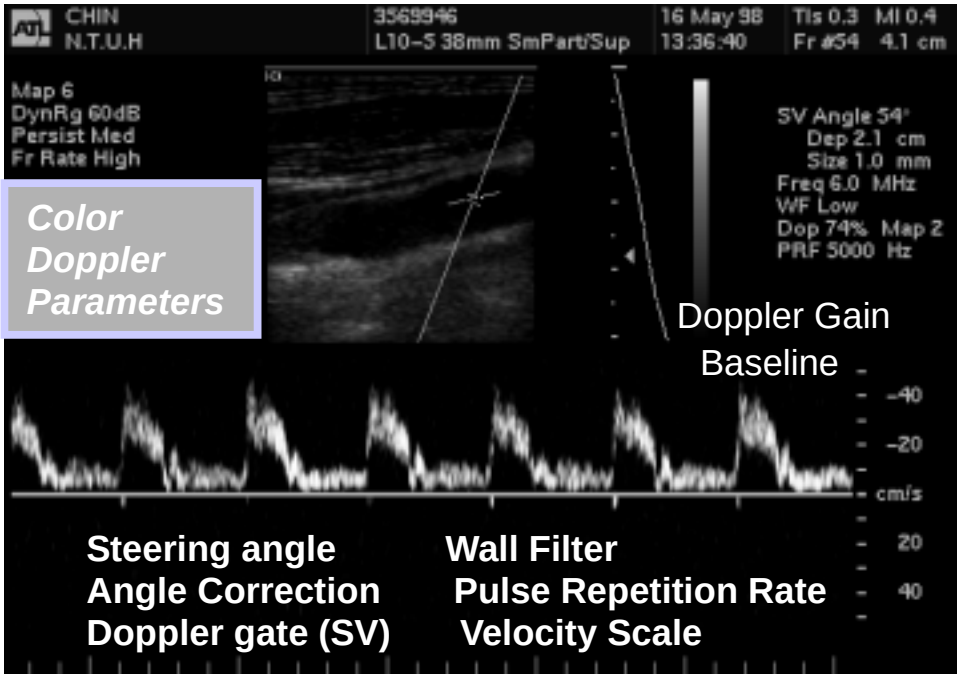


CW vs. PW Doppler Ultrasound Measurements

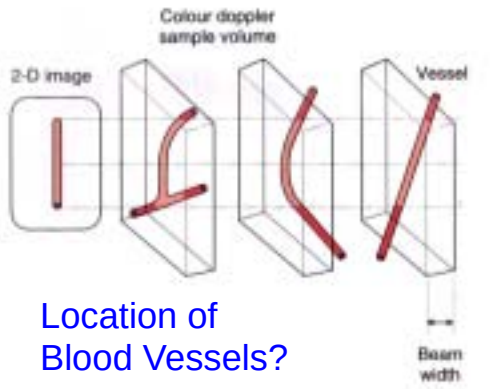
Continuous Wave (CW) Doppler	Pulse Wave (PW) Doppler
+ Sensitivity	+ Spatial resolution
+ Inexpensive	+ Visibility and Focusing
+ High S/N ratio	+ Angle correction
+ Low power	- High power
- No spatial information	- Low S/N ratio

Color Doppler Sonography

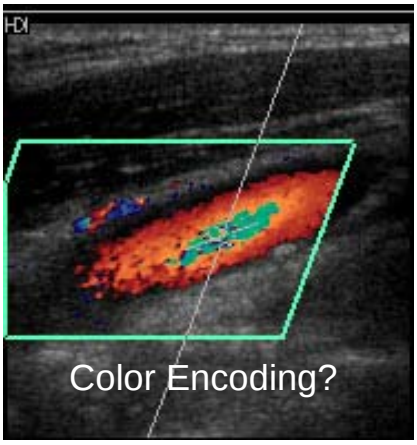
Color Doppler has become an essential method in medical image diagnosis. A color Doppler image consists of gray-scale image that shows the morphological information of the object interested. Color is added to the image where moving objects that cause Doppler frequency-shifts are observed and the intensity reflect the magnitude of velocity.

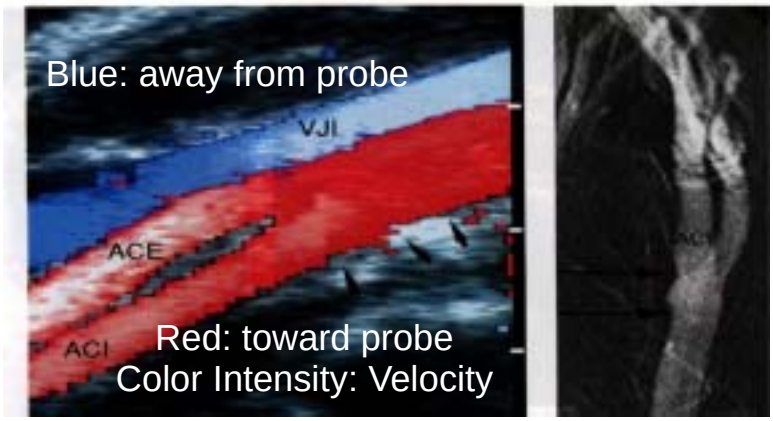


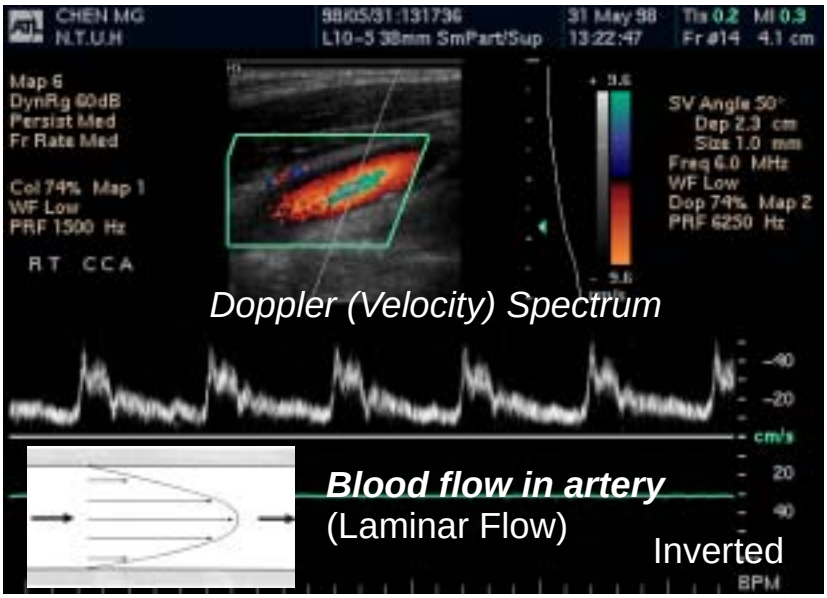
Color Doppler for finding Blood Vessel

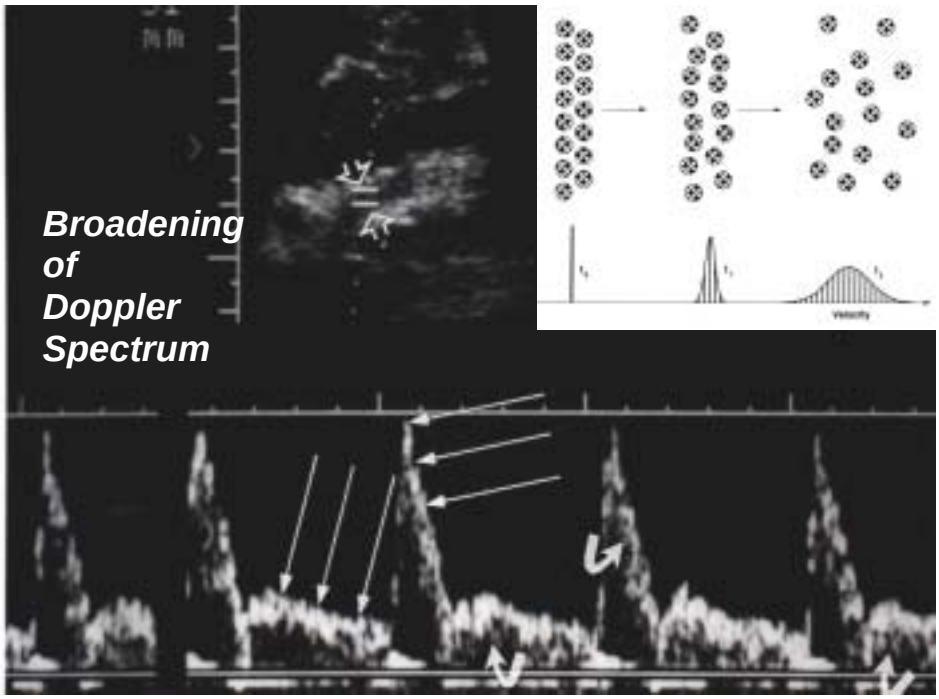


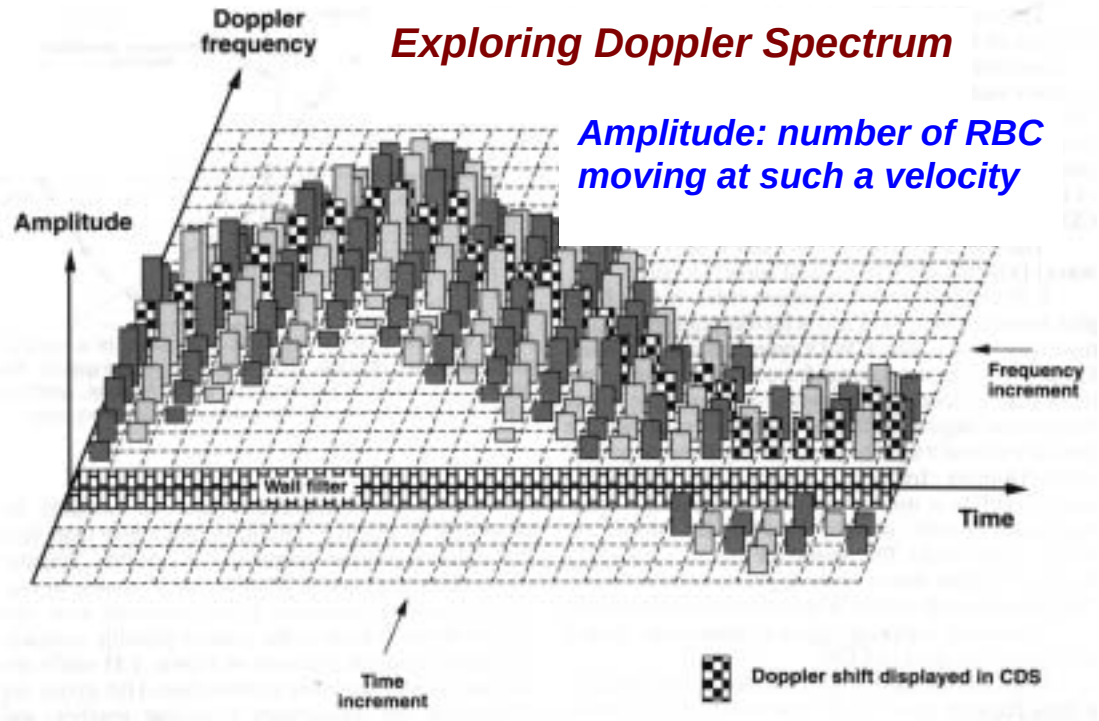
Location of
Blood Vessels?

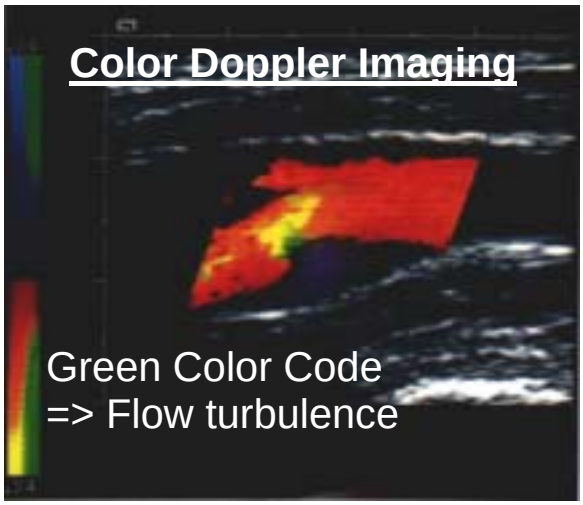


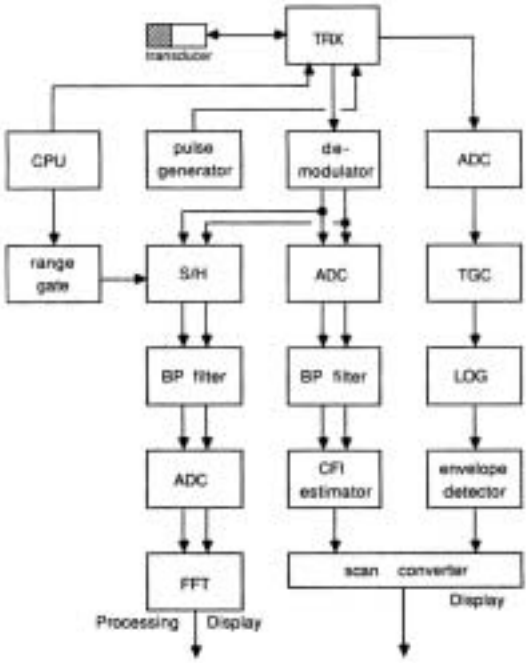





Broadening
of
Doppler
Spectrum

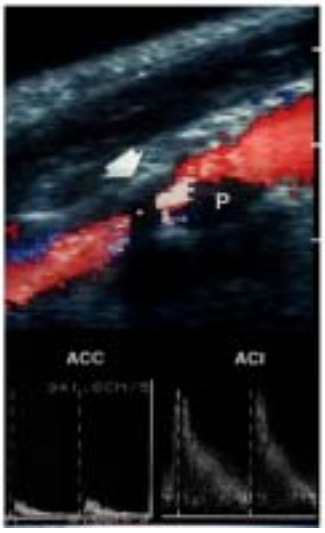

Doppler
frequency
Exploring Doppler Spectrum
Amplitude: number of RBC
moving at such a velocity
Amplitude
Frequency
increment
Wall filter
Time
Time
increment
Doppler shift displayed in CDS





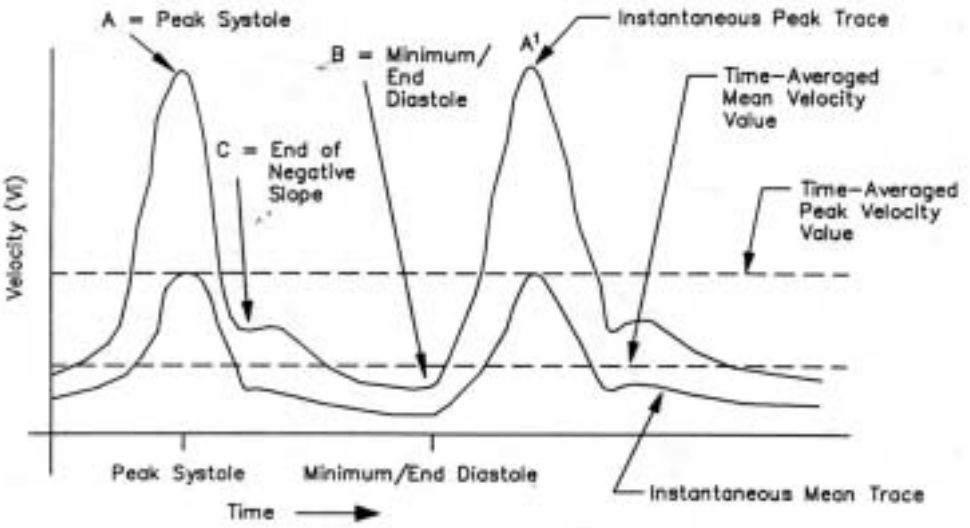
Clinical Applications of Color Doppler Ultrasound

- ✧ *Arterial Stenosis (turbulent jet)*
- ✧ *Arterial Resistance*
- ✧ *Tumor Vascularity (feeding artery Doppler spectrum)*
- ✧ *Vascularity of Renal/Liver Transplants (predicting rejection)*
- ✧ *Tumor Vascularity (angiogenesis, malignancy and metastases)*



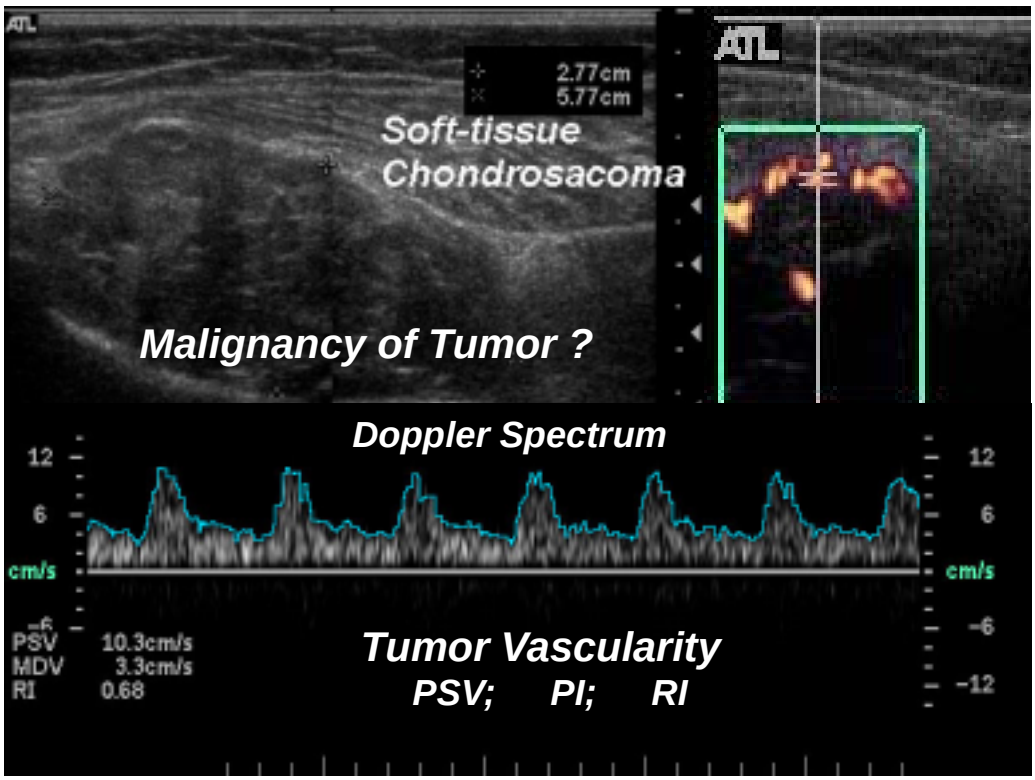
Stroke
(ICA stenosis)

Doppler Spectrum Flow index

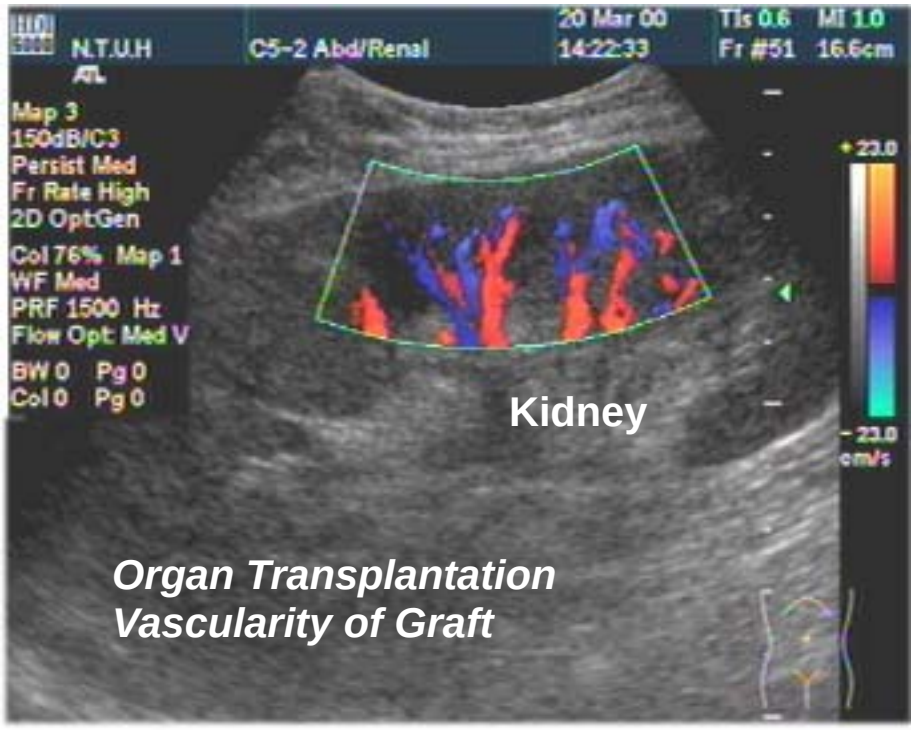


PS : Peak Systolic flow **ED: End Diastolic flow**

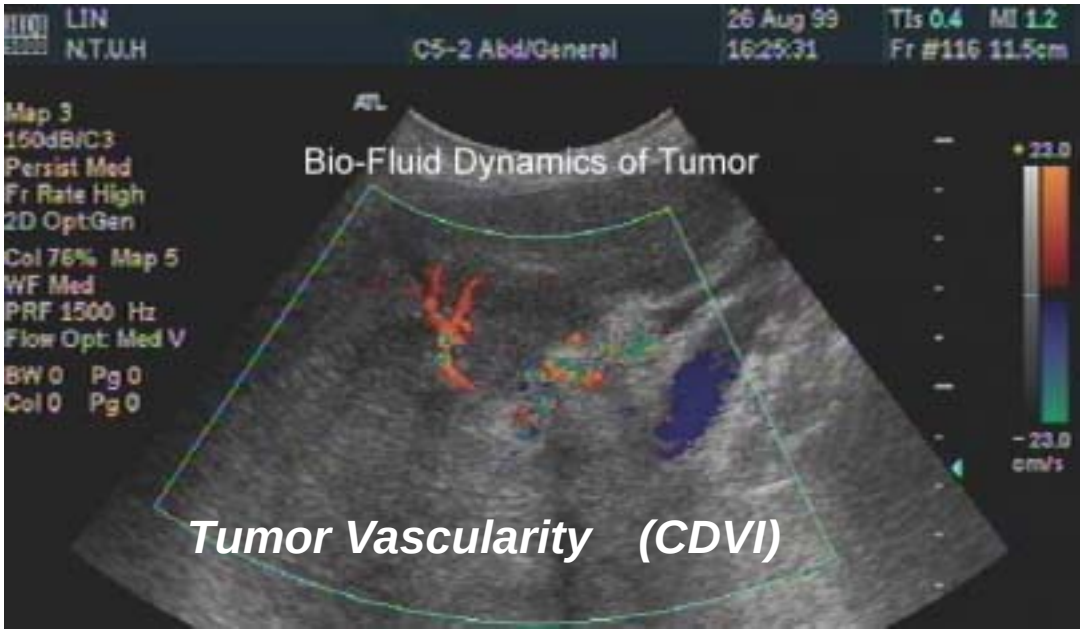
- **Resistive Index = (PS-ED)/PS**
- **Pulsatility index = (PS-ED)/Mean**
- **PS/ED ratio**

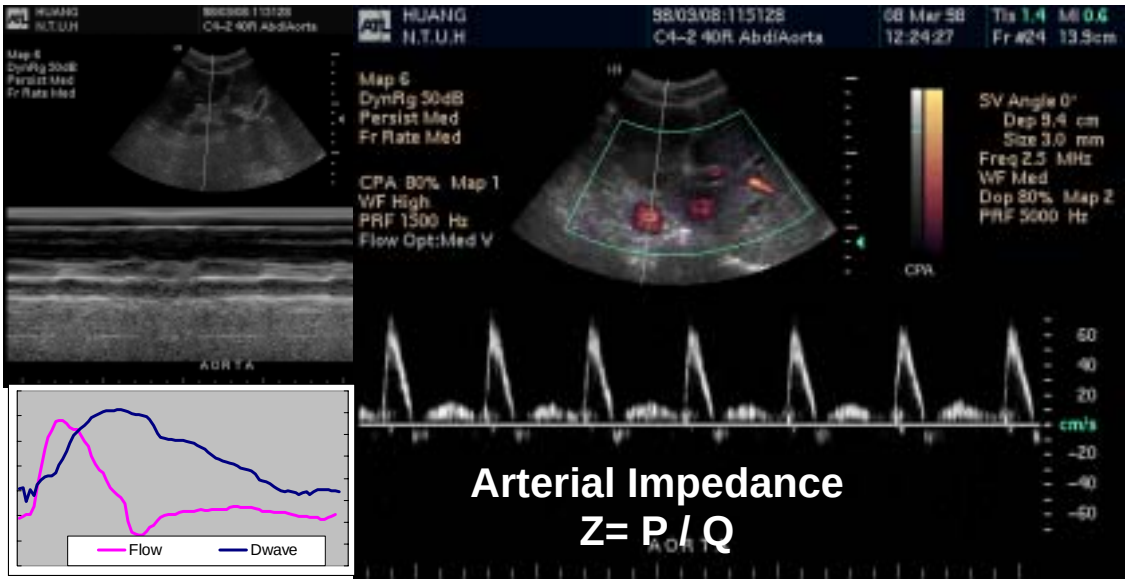


Vascularity of Renal/Liver Transplants



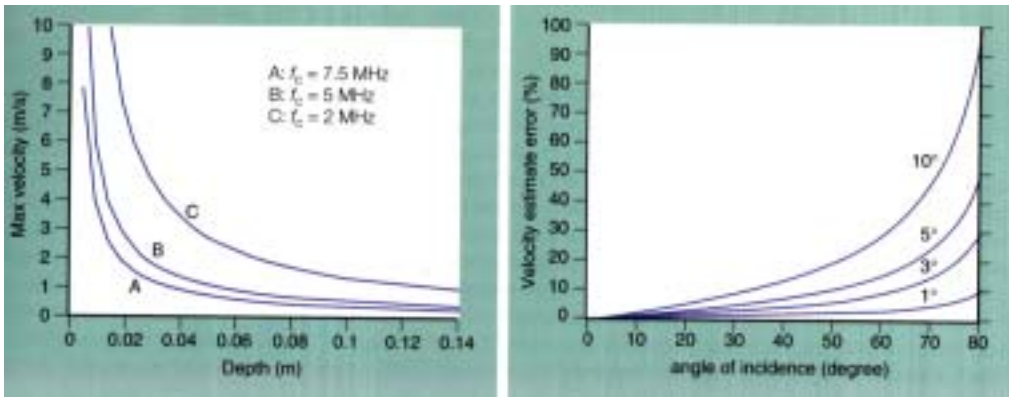
Tumor Vascularity (angiogenesis, malignancy and metastases)



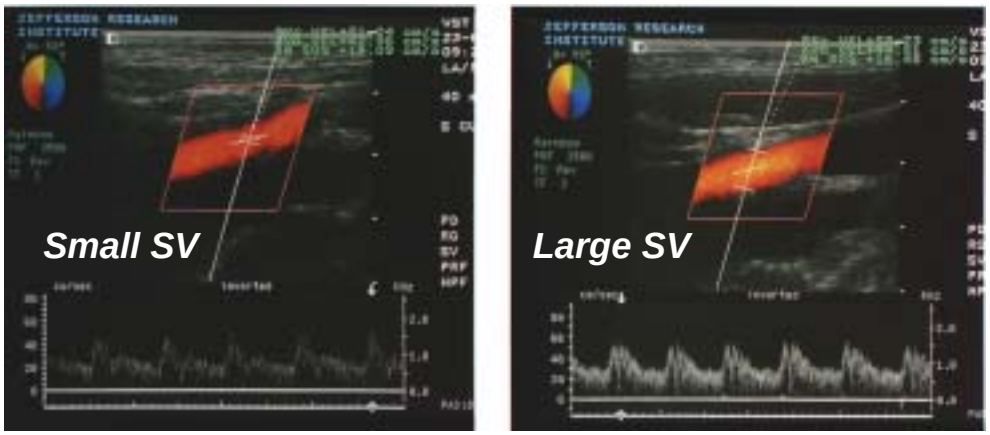


Ambiguity of Color Doppler Ultrasound

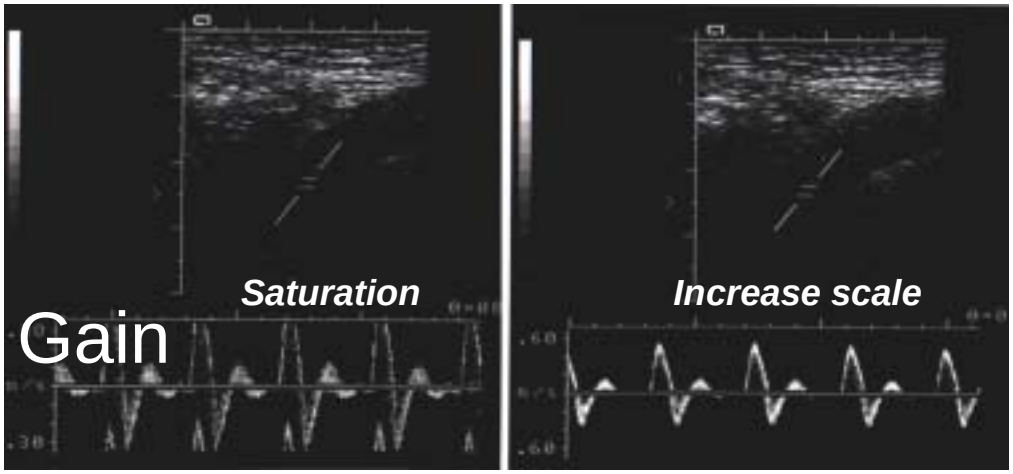
- ✧ *Dependence of depth and angle of incidence*



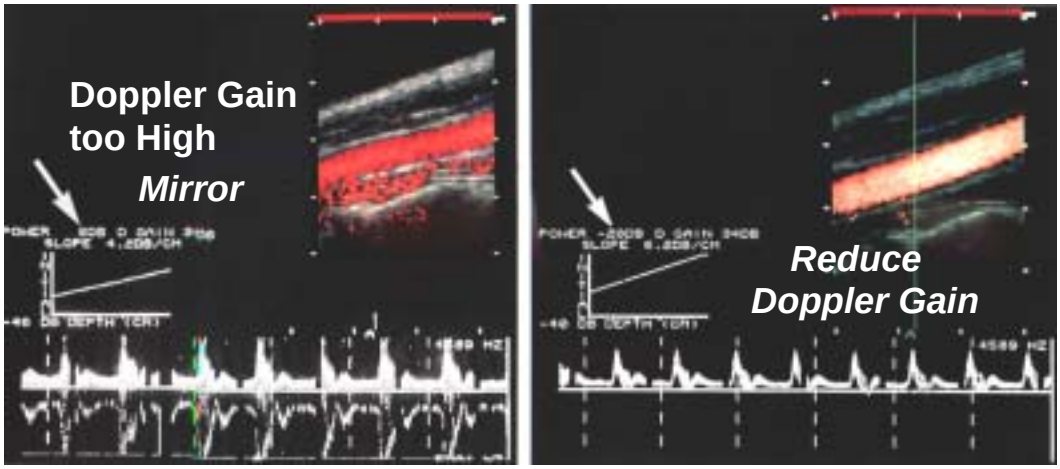
- ✧ *Effect of Doppler Sampling Volume (gate)*



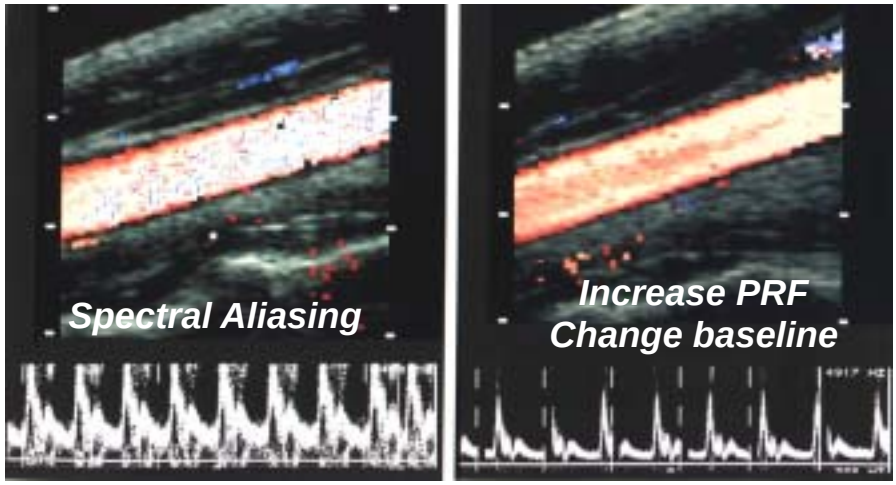
✧ *Effect of Scale*



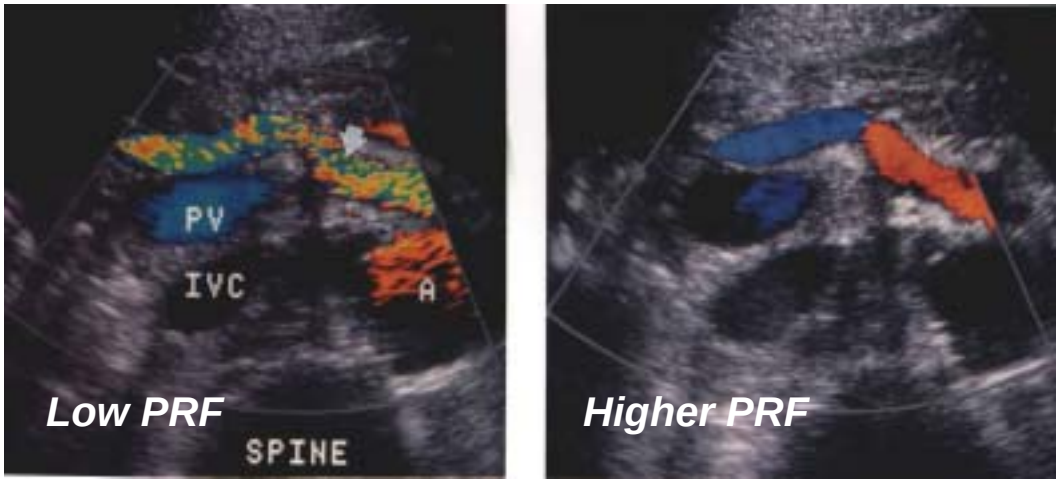
✧ *Effect of Doppler Gain*



✧ *Effect of Pulse Repetition Frequency (PRF)*



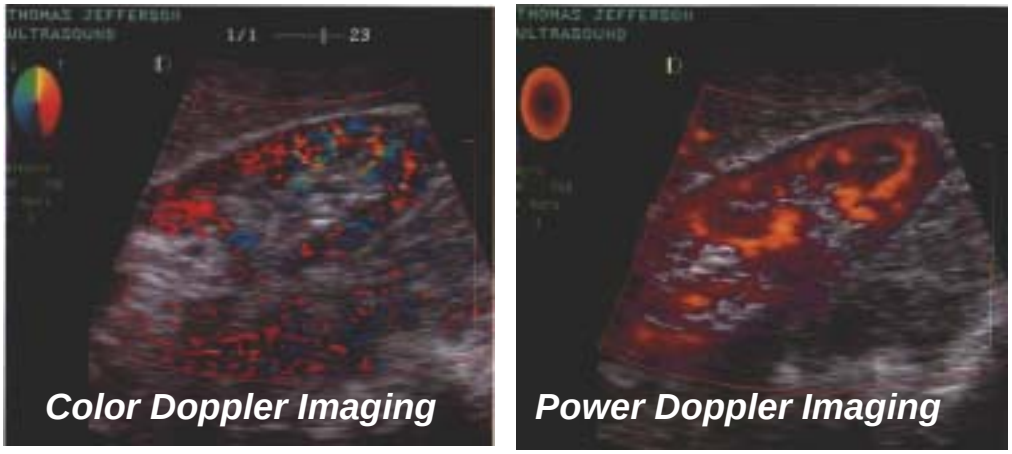
Use of Color Doppler artifact in abdominal scanning



Low PRF results in higher sensitivity of flow detection (venous flow)

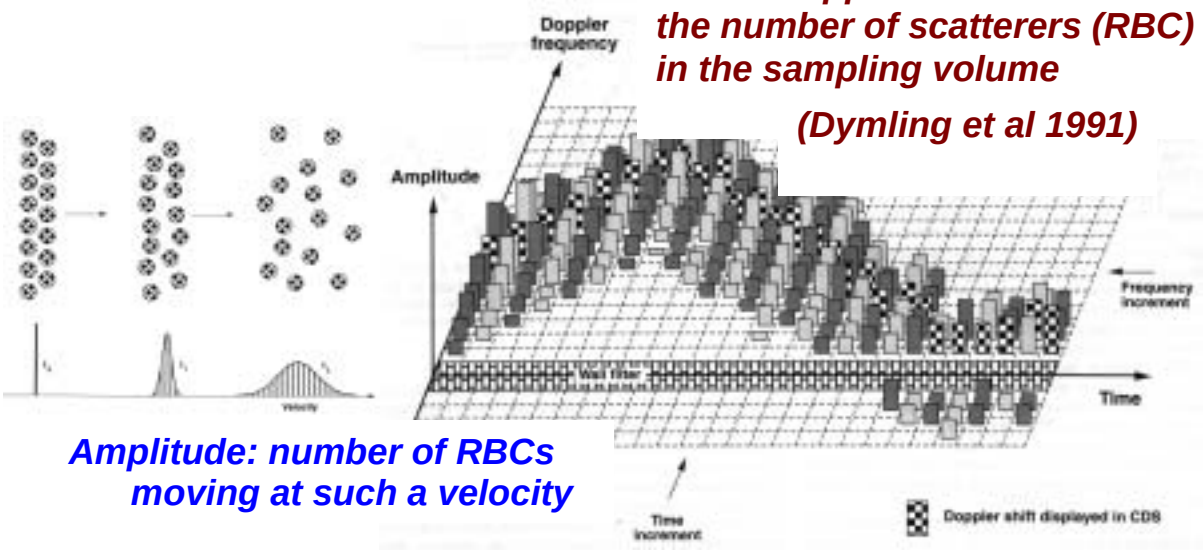
Power Doppler Imaging

Power Doppler is a new method of ultrasound flow imaging that based on the integrated power of the Doppler spectrum rather than the mean Doppler spectrum. Power Doppler imaging is more sensitive in terms of blood flow detection than conventional color Doppler, thus it has the potential of displaying tissue perfusion. Since the strength of power Doppler is proportional to the ***number of scatterers*** *(RBCs) flowing through the region-of-interest (ROI). Its relation to the flow volume is quite complex. Nevertheless, it is inherently unaffected by aliasing (i.e., low PRF) and relatively insensitive to the insonating angle or scanning depth.*



Power Doppler measures the number of scatterers (RBC) in the sampling volume

(Dymling et al 1991)

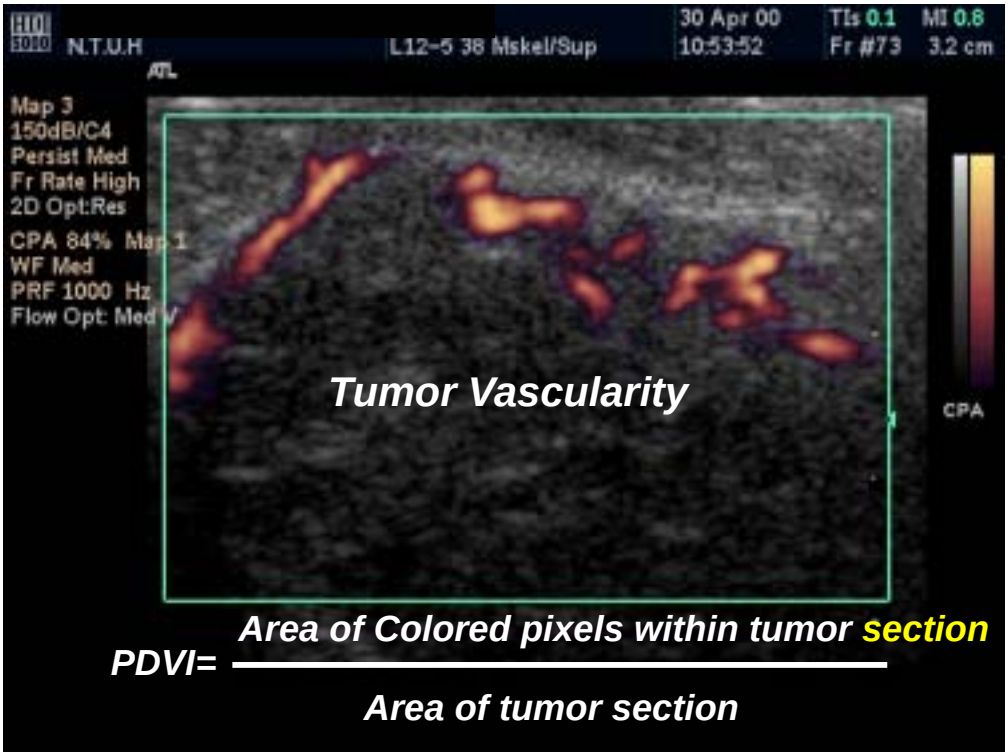


Amplitude: number of RBCs moving at such a velocity

Clinical Applications of Power Doppler Ultrasound

*Since the **power Doppler (PD)** can **quantify** the fractional of moving blood volume through the ROI, attempts have been made to investigate the **soft tissue perfusion** in various hypervascular microvessel beds. The power Doppler imaging are often normalized and optimized to enhance the signals of moving scatters at low velocities (0.8 – 6 cm/sec), its magnitude does not proportional linearly to blood velocity. However, due to high sensitivity of tissue perfusion, the potential applications of PD are:*

- ✧ *vascularity in normal and transplanted renal tissues for rejection prediction,*
- ✧ *tumor vascularity for malignancy and metastases*
- ✧ *placental vascularity for possible previa accreta,*



Comparison of PW Doppler Spectrum , CDI , CPA

	PWDS	CDI	CPA
Region of Interest	Small	Large	Large
Spatial Resolution	Poor	Fair	Fair
Temporal Resolution	Good	Fair/Poor	Poor
Flow Sensitivity	Good	Fair	Good
Flow magnitude	Detailed	Fair	Poor
Vessel size	medium	medium	small

超音波都卜勒重要參數

- 超音波之探頭形狀(Linear Array、Sector)
- 超音波之探頭頻率(2 - 30MHz)
- 超音波之發射能量(Transmit Power Level)
- 脈波發射頻率(Pulse Repetition Frequency)
- *Insonatinf angle*; 掃描線與血管之夾角 ($\alpha < 70$ deg)
- *Doppler Gain*
- *Scale*
- *CPA Gain (Power Doppler)*

Concluding Remarks

- *Doppler Ultrasound provide a way of measuring blood flow non-invasively*
- *Hemodynamics is important physiologically and clinically*
- *Color Doppler Imaging gives blood velocity in vessels of order of a few hundred microns*
- *Power Doppler Imaging for microvessel perfusion (higher sensitivity and resolution)*
- *Color Doppler and Power Doppler look into different physics of flow in human body*