Principles of Ultrasound Imaging
Image Optimization

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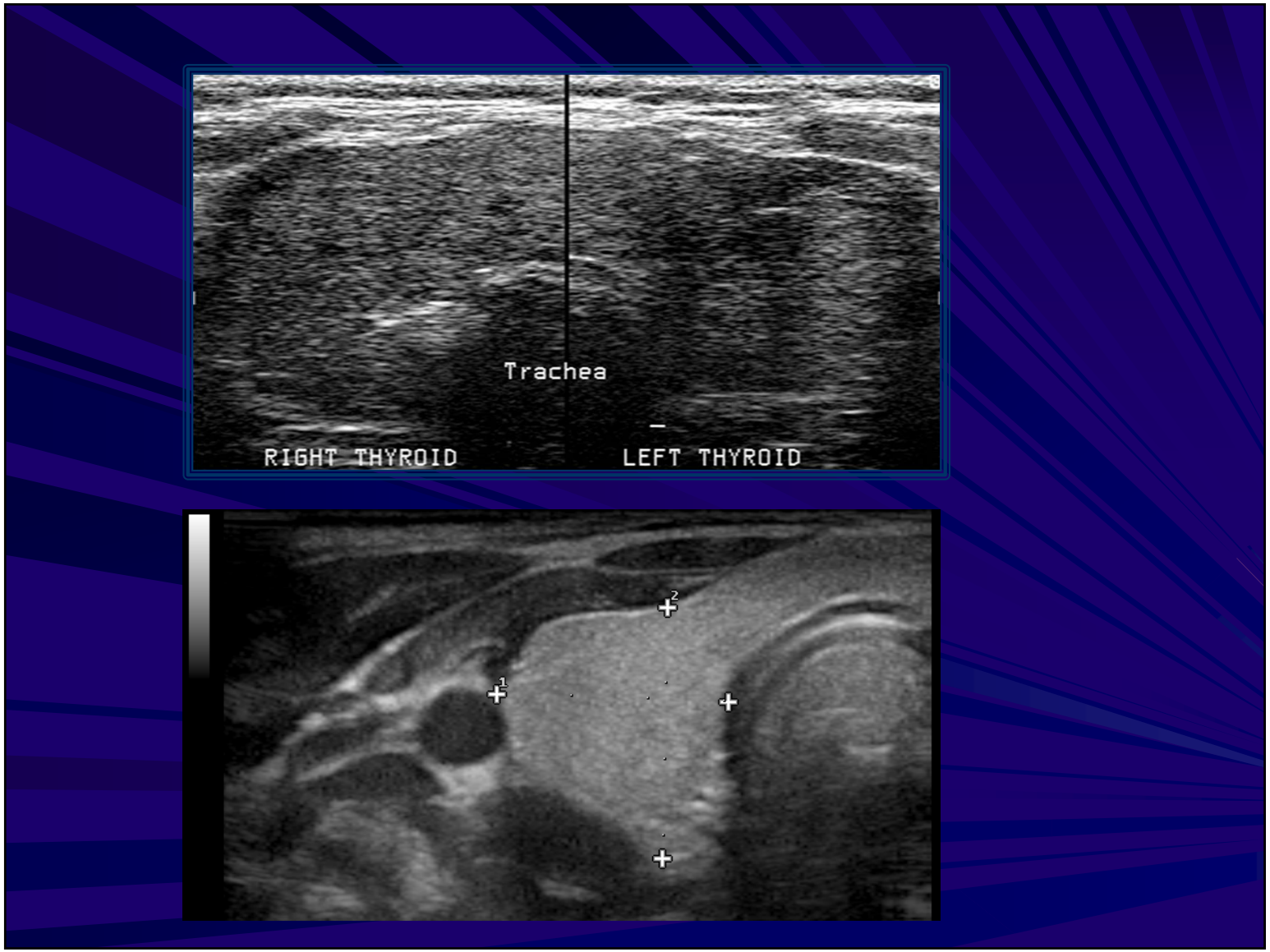
Image Optimization

Create the sharpest image to allow tissue discrimination.

- Equipment factors:
  - Quality of Transducer
  - Quality of Electronics
  - Image Enhancement and Compound Imaging
- User Adjustments:
  - Depth, Gain, Frequency
  - Focal zones – Number and Location
  - Compound Imaging
  - Tissue Harmonic Imaging
  - Dynamic range



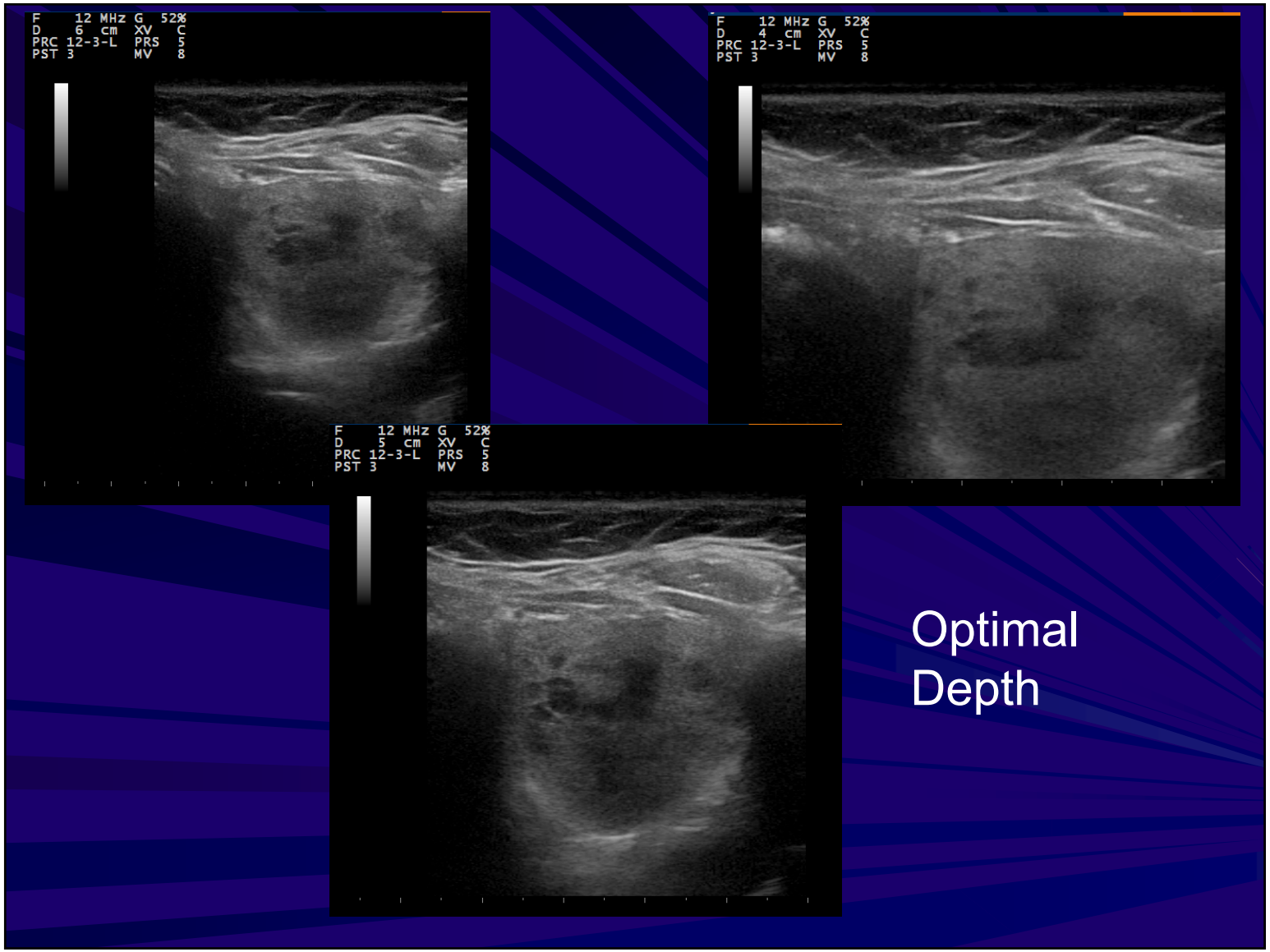
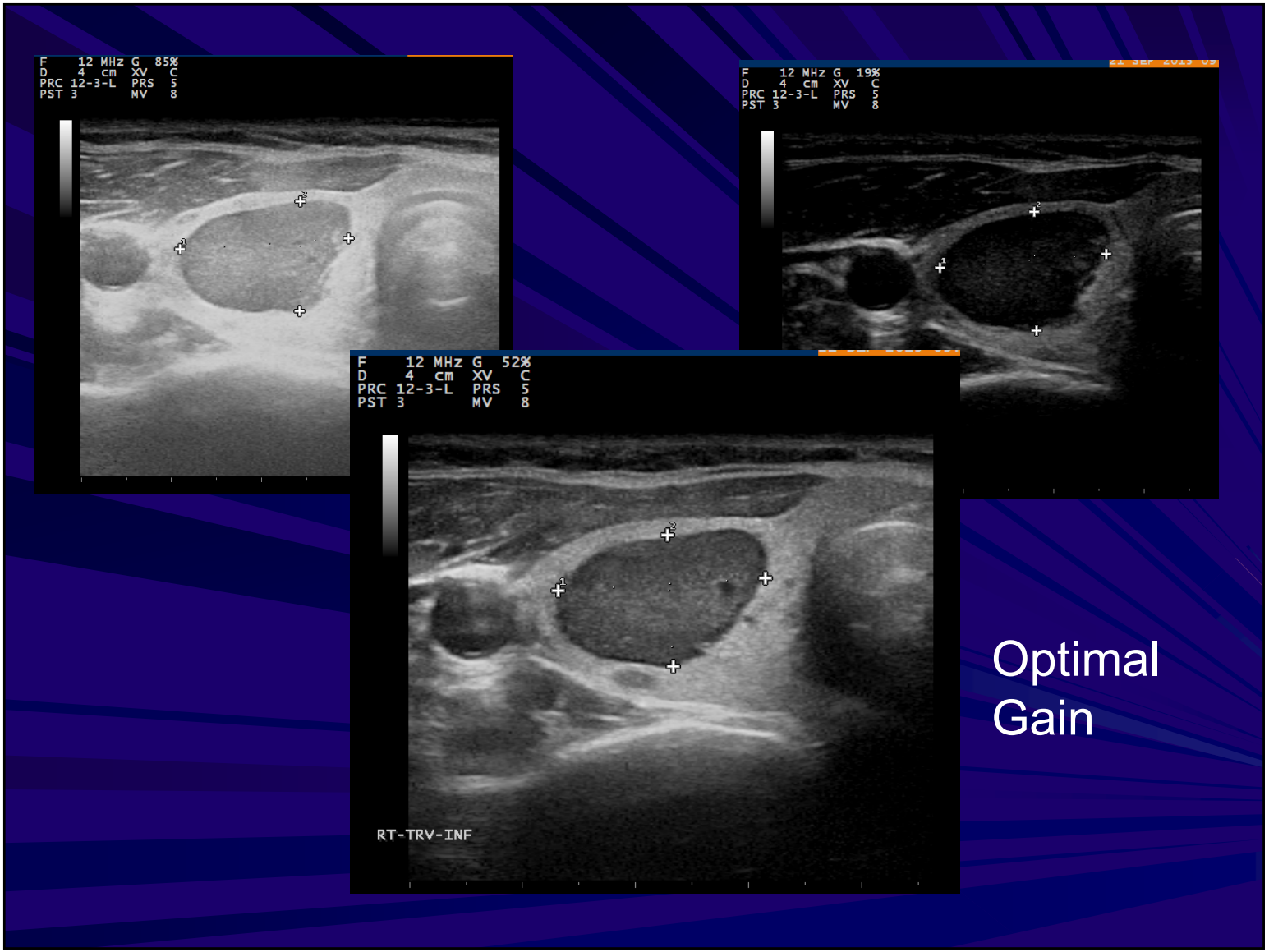
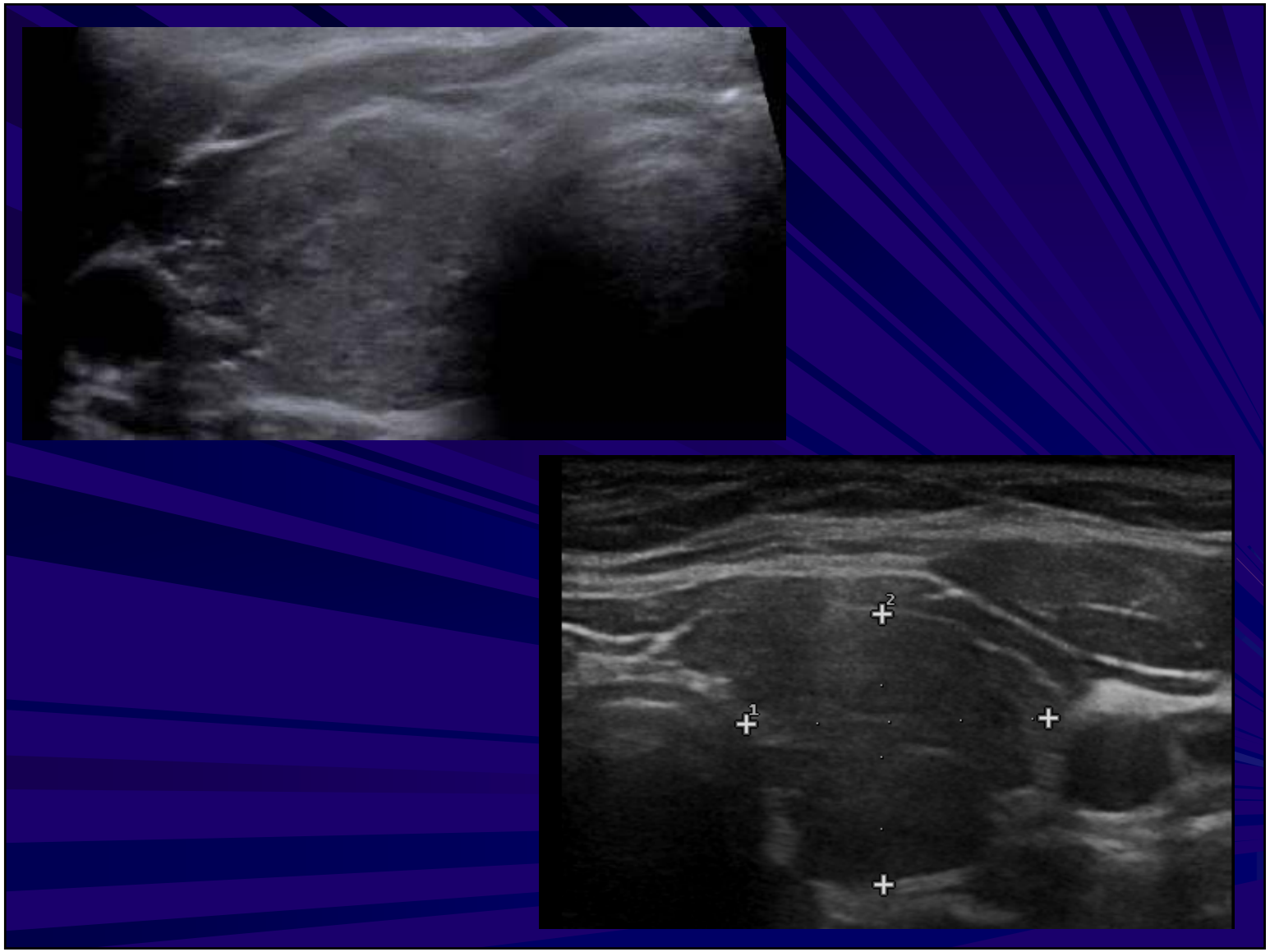


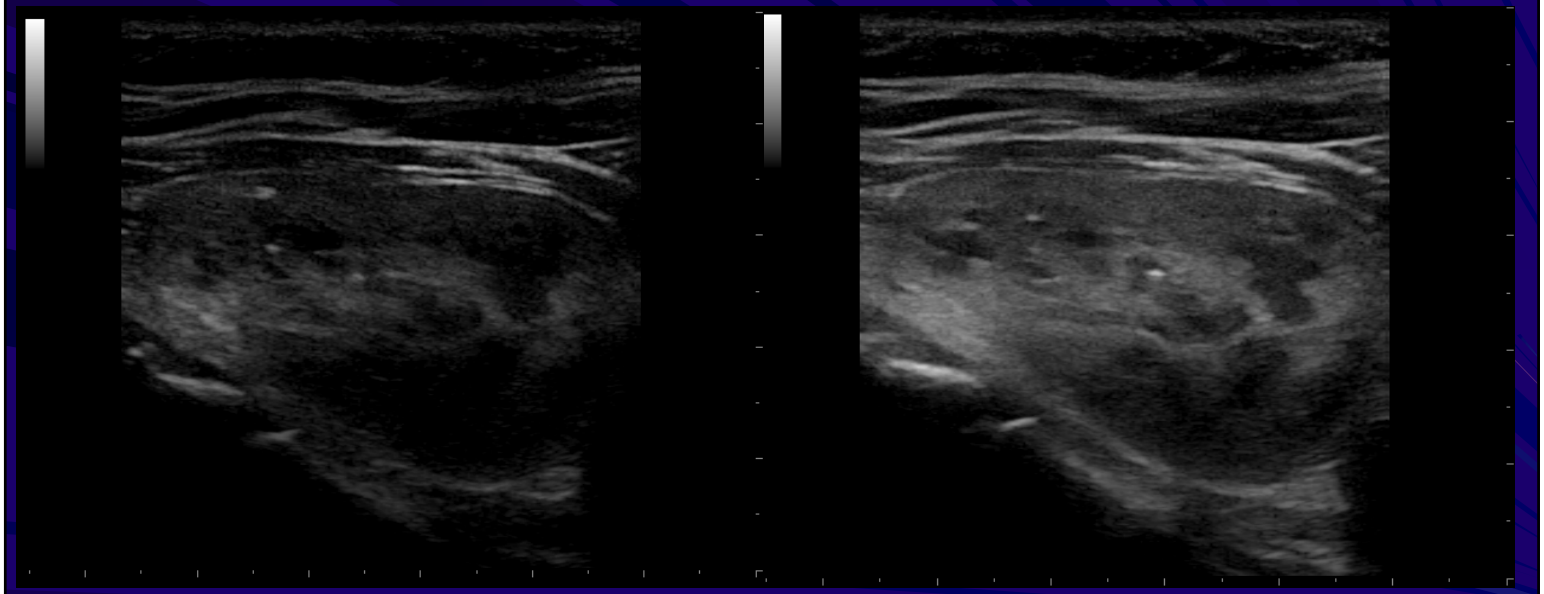
Image Optimization

- Gain
  - Overall Gain
  - Time Gain Compensation
    - Multiple channels corresponding to depth
    - User adjustable to achieve best image quality at region of interest
- Focal Zone(s)
  - Adjustable depth and number
  - Greater number of zones slows refresh rate





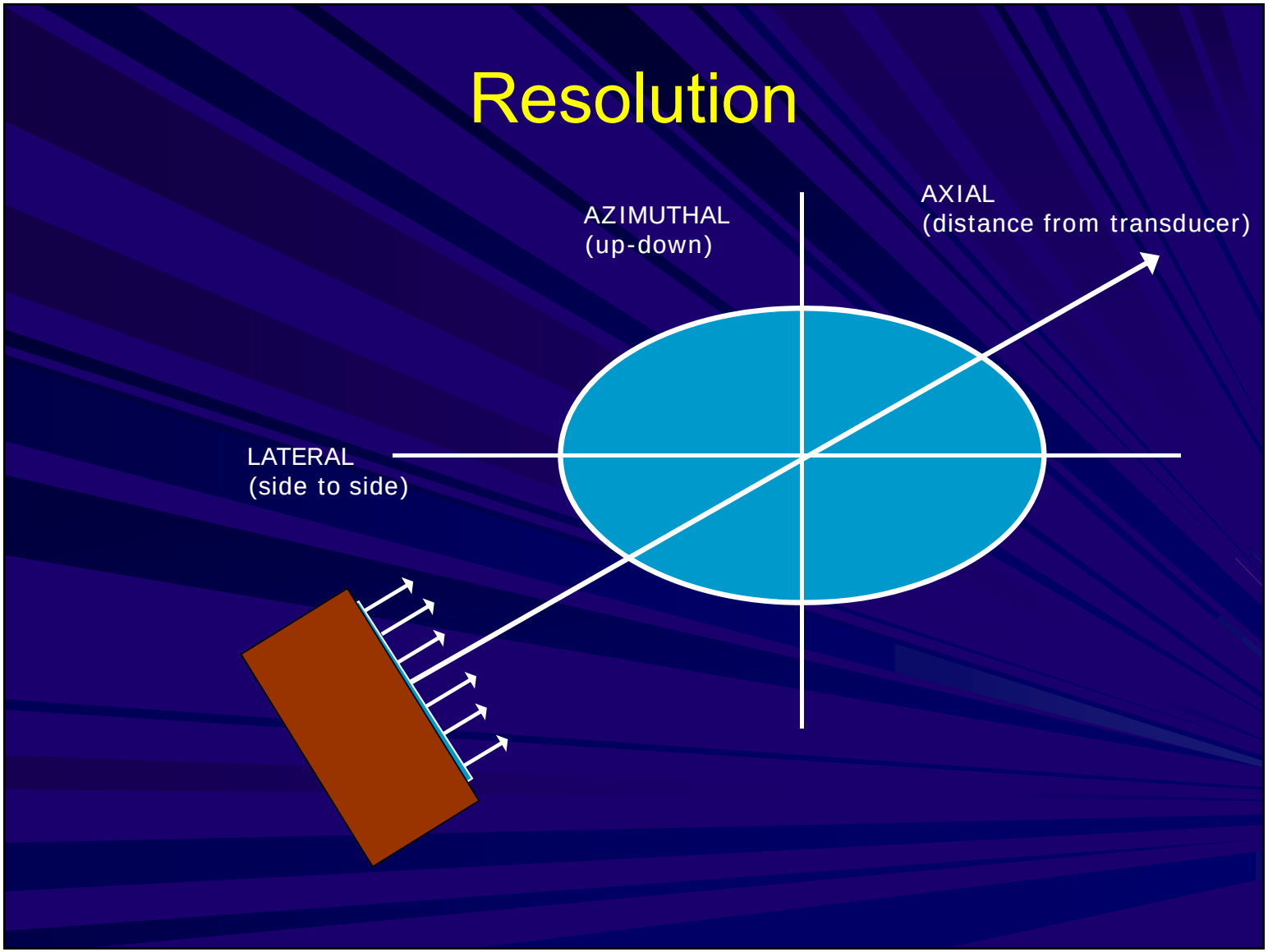
Optimal
Time Gain Compensation



Resolution

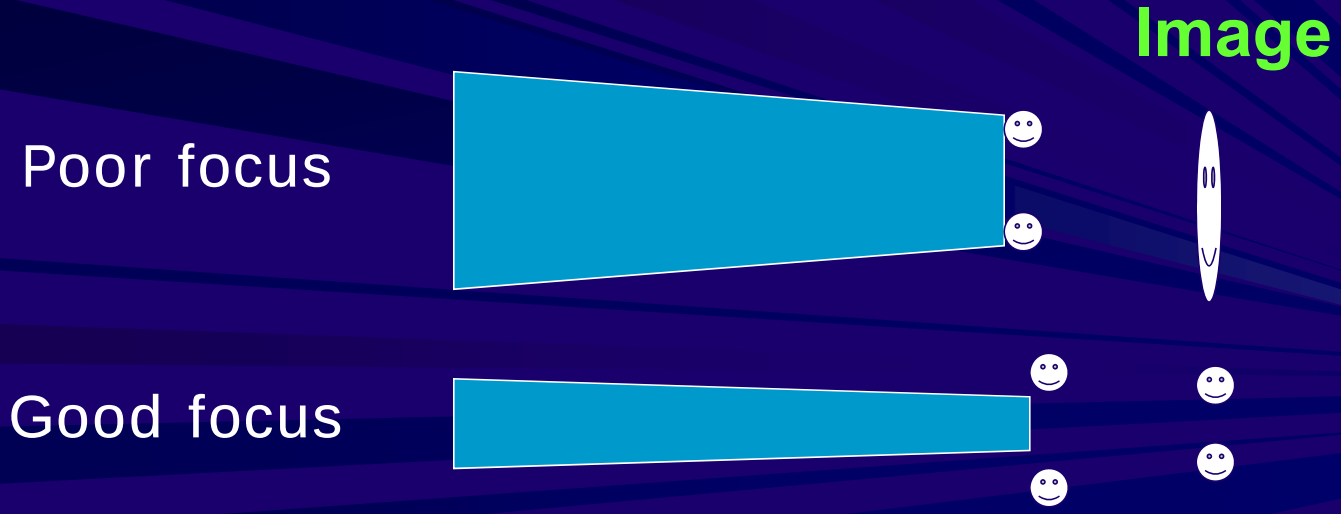
- Resolution is the ability to discriminate two structures as separate entities
- Types of resolution :
  - Axial (distance from the transducer)
  - Lateral (transverse)
  - Azimuthal (thickness of imaging plane)

Resolution



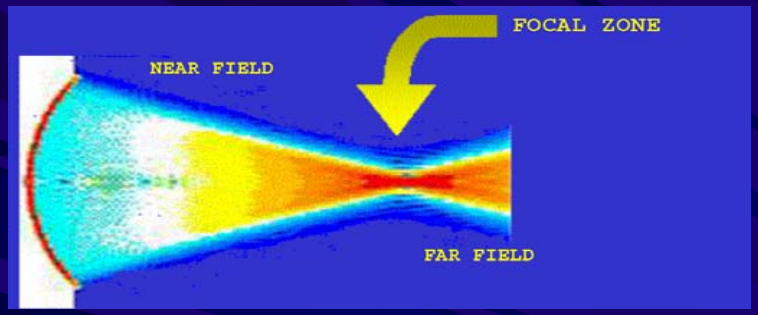
Resolution

- Ability to discriminate two adjacent objects as separate entities.
- The narrower the beam, the better the lateral resolution. The higher the frequency the better the axial resolution.



Focus and Resolution

- Focused beam width determines Lateral and Azimuthal Resolution

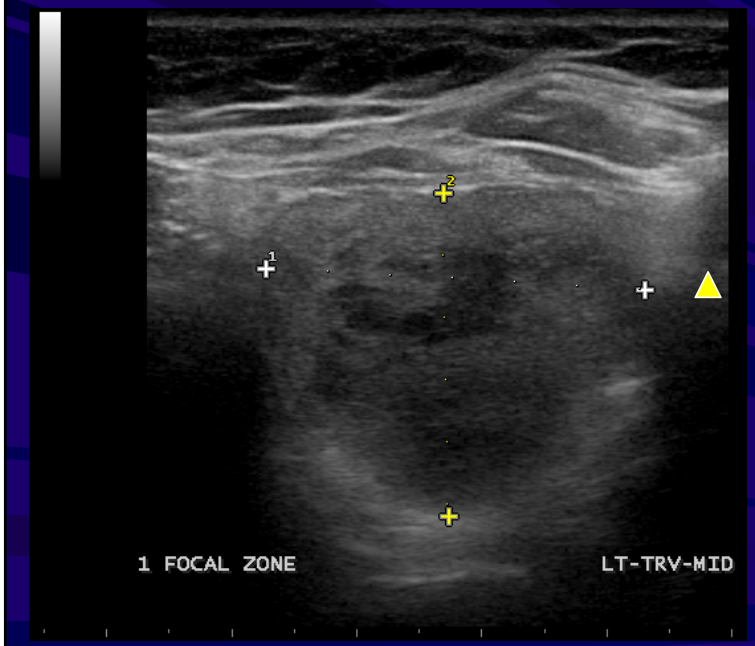


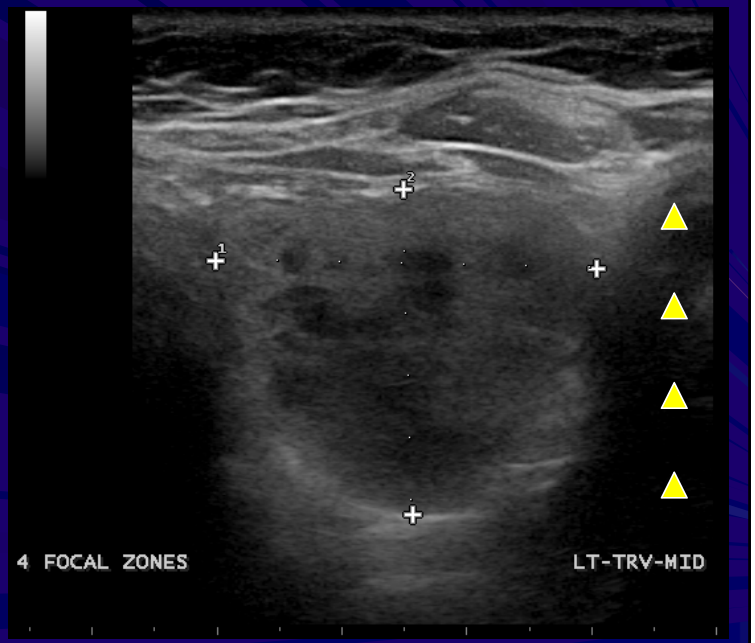
Near field (Fresnel Zone)
Large variations of intensity

Far field (Fraunhofer Zone)
Greater variation with greater distance.
Focal Zone - Area of maximal narrowing

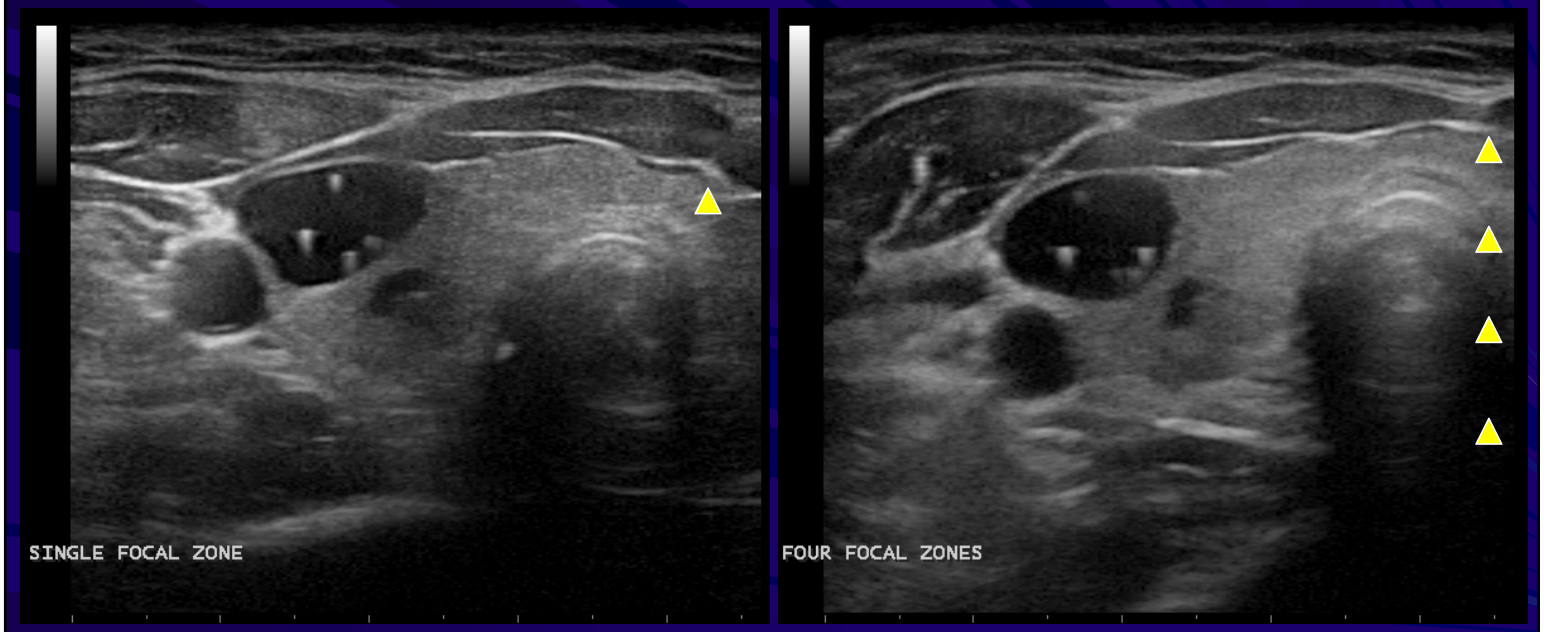
- Pulse duration (frequency) determines Axial Resolution
  - (axial resolution = 1/2 spatial pulse length)
- Practical Consideration - As frequency increases, axial resolution improves, but depth of imaging decreases.
  - The number and depth of the focal zones are often adjustable and indicated on the display

Adjustment of number and position of focal zones

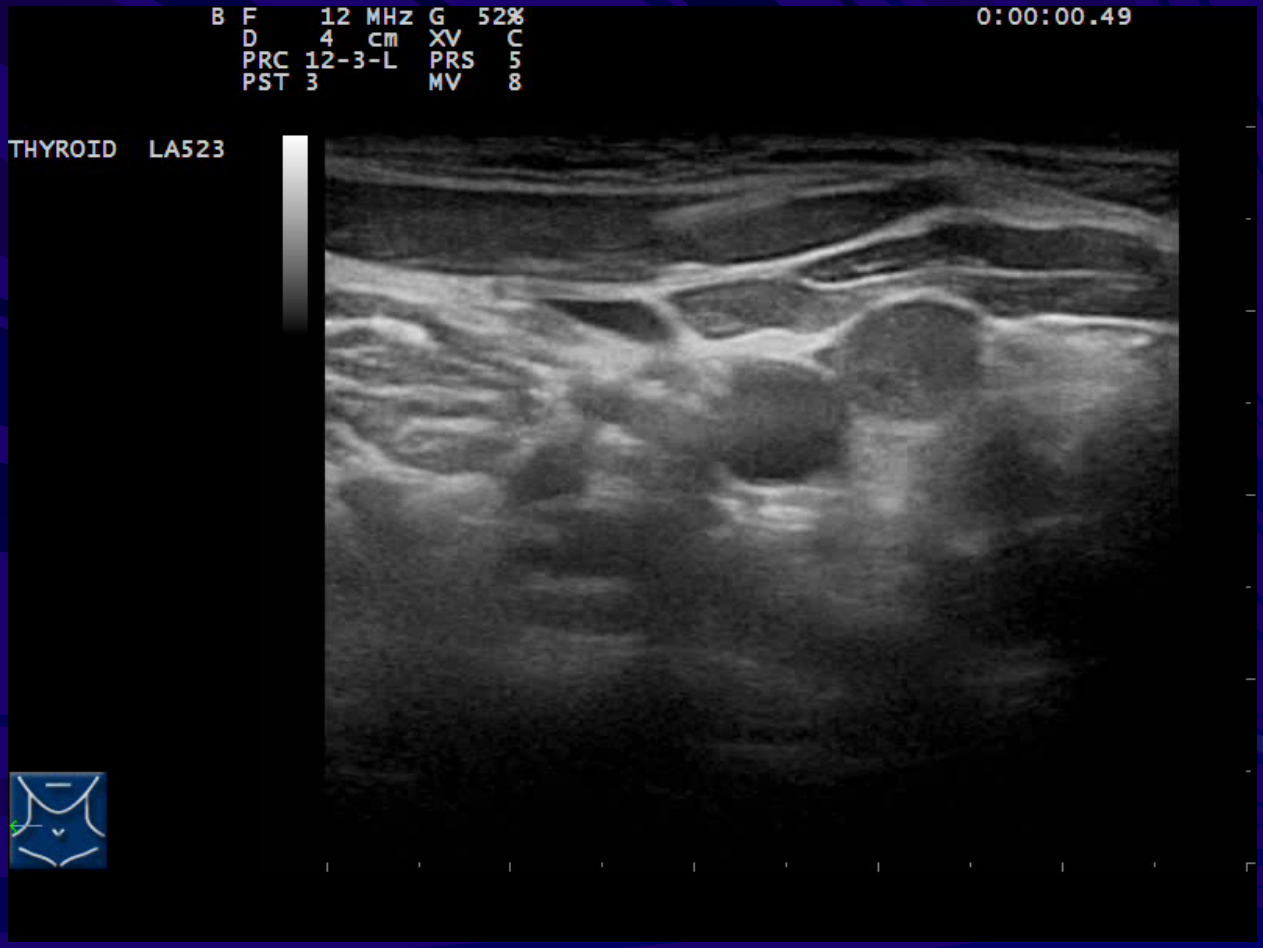




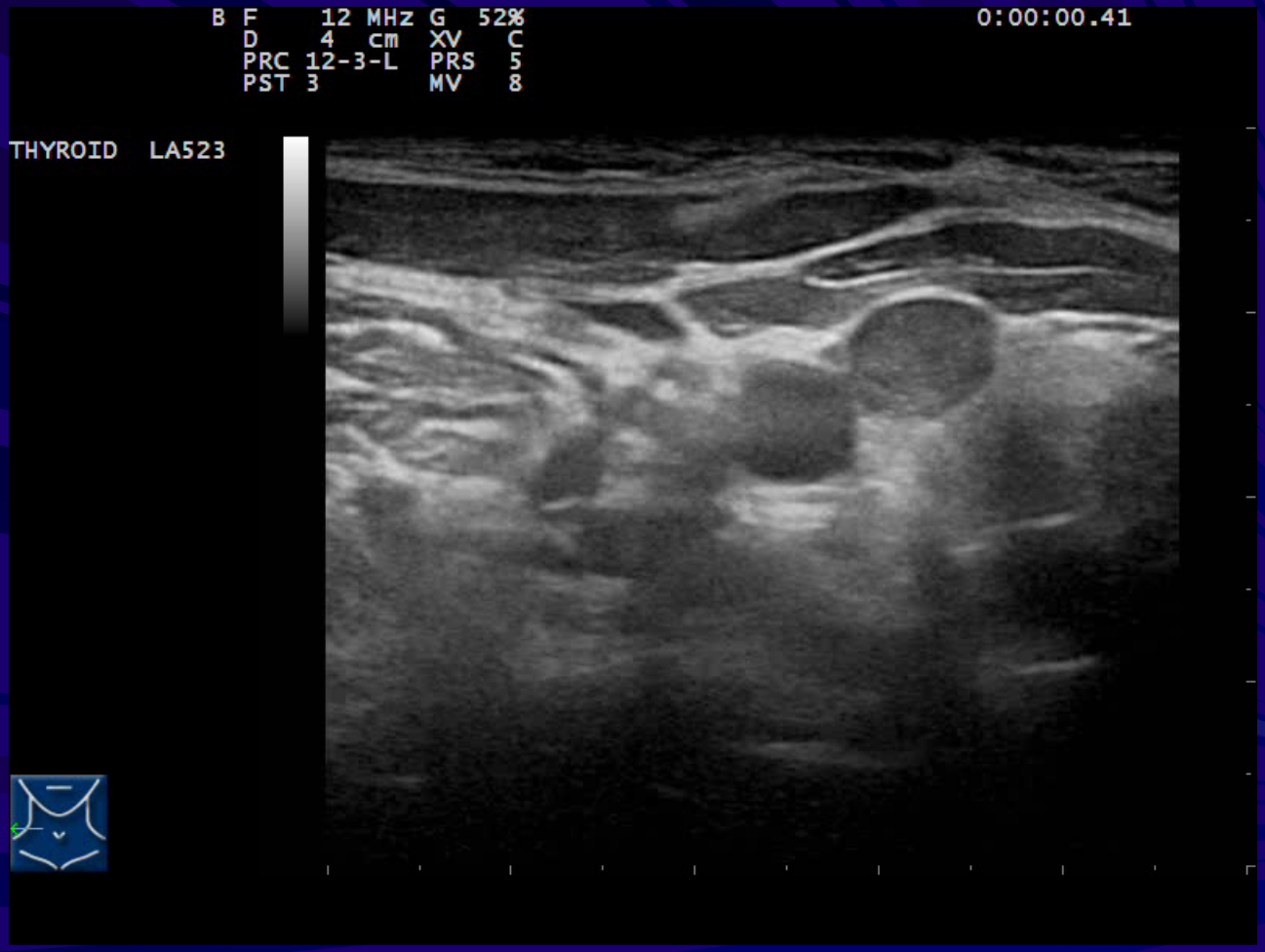
Adjustment of number and position of focal zones



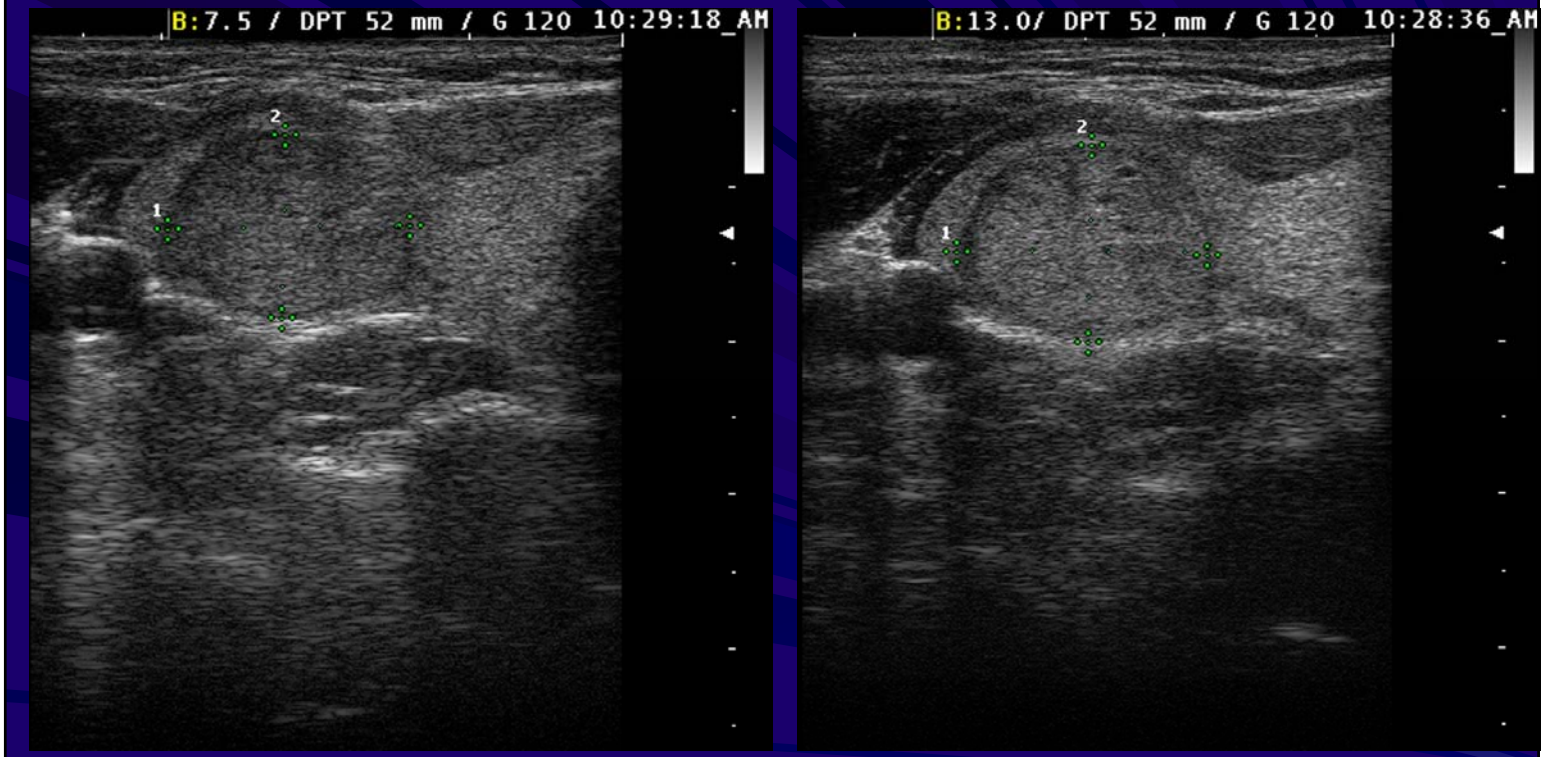
Single focal zone



Four focal zones



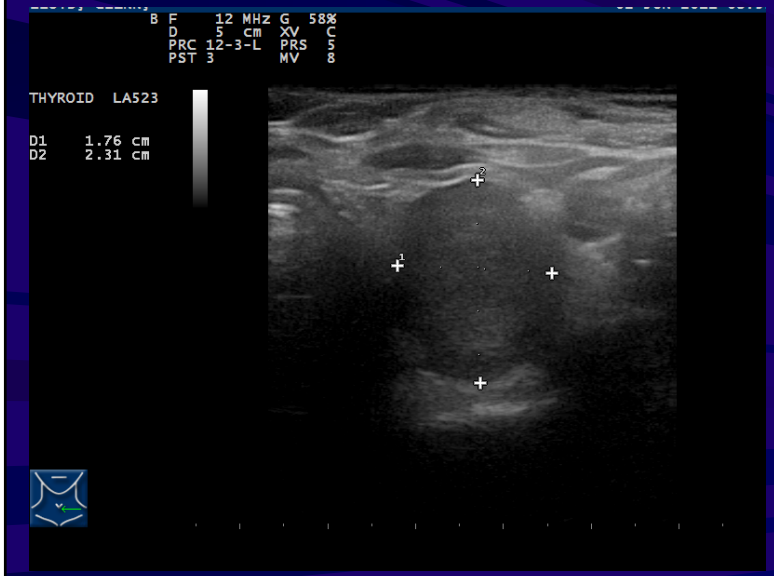
Frequency and Resolution

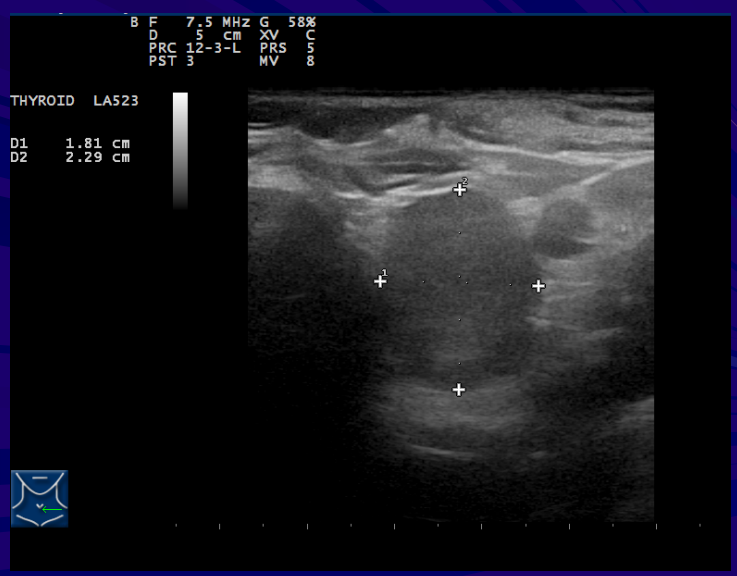


Higher frequency gives better resolution.
Higher frequency gives less penetration.
Need to find best compromise for depth of interest

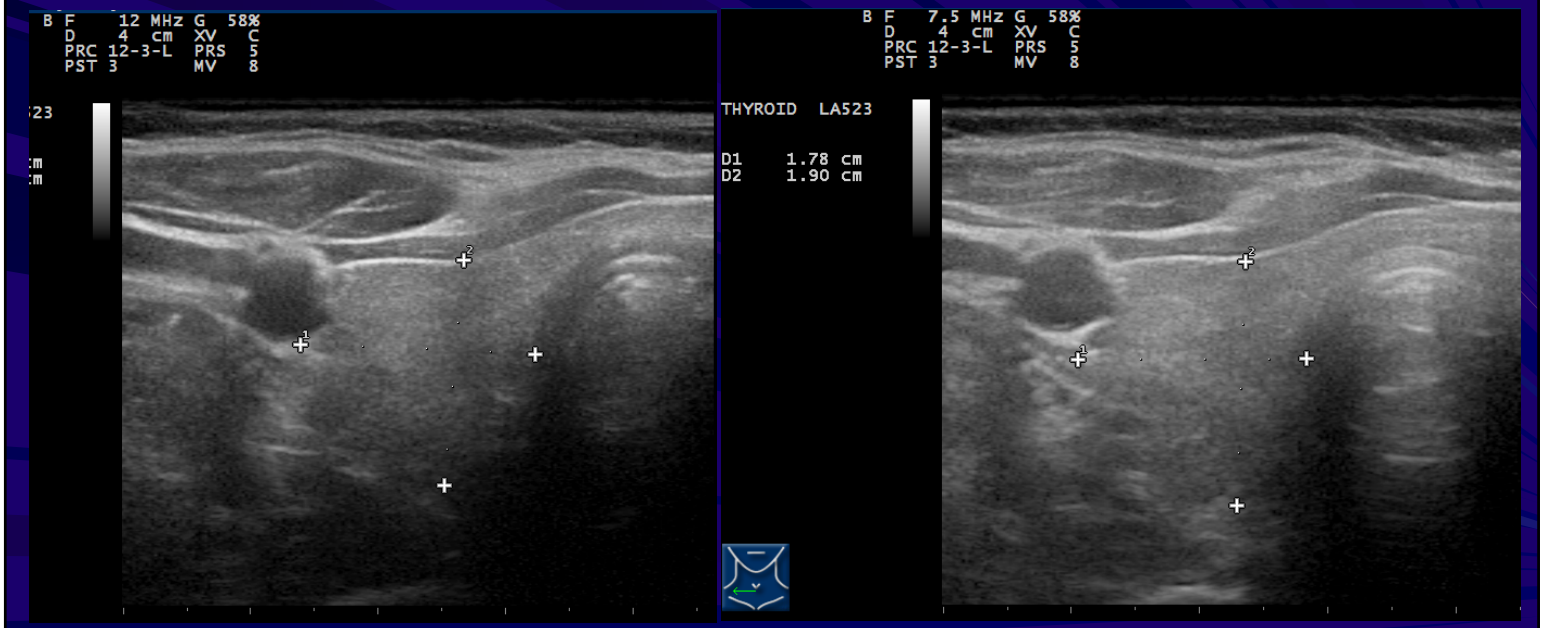
Image Optimization - Frequency

- Choose highest frequency (12-15 MHz) that allows adequate depth penetration.
- Lower frequencies (7-10 MHz) for deep structures or very obese subjects





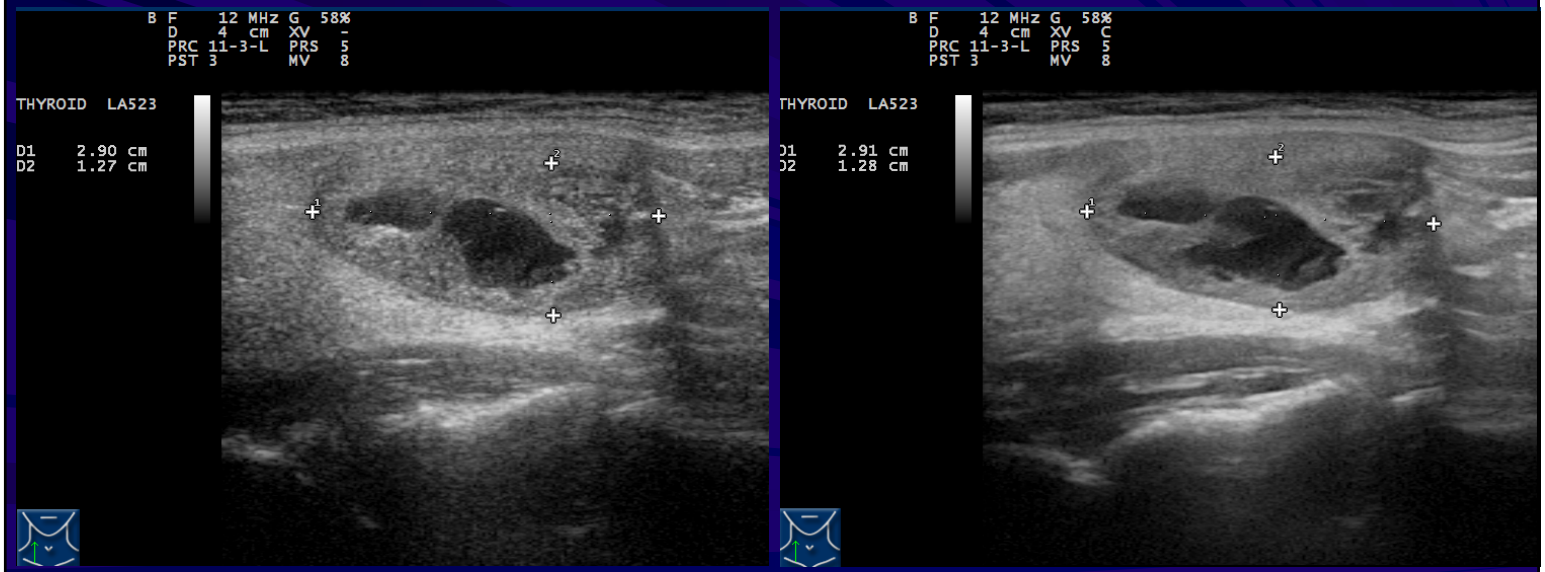
Frequency and depth



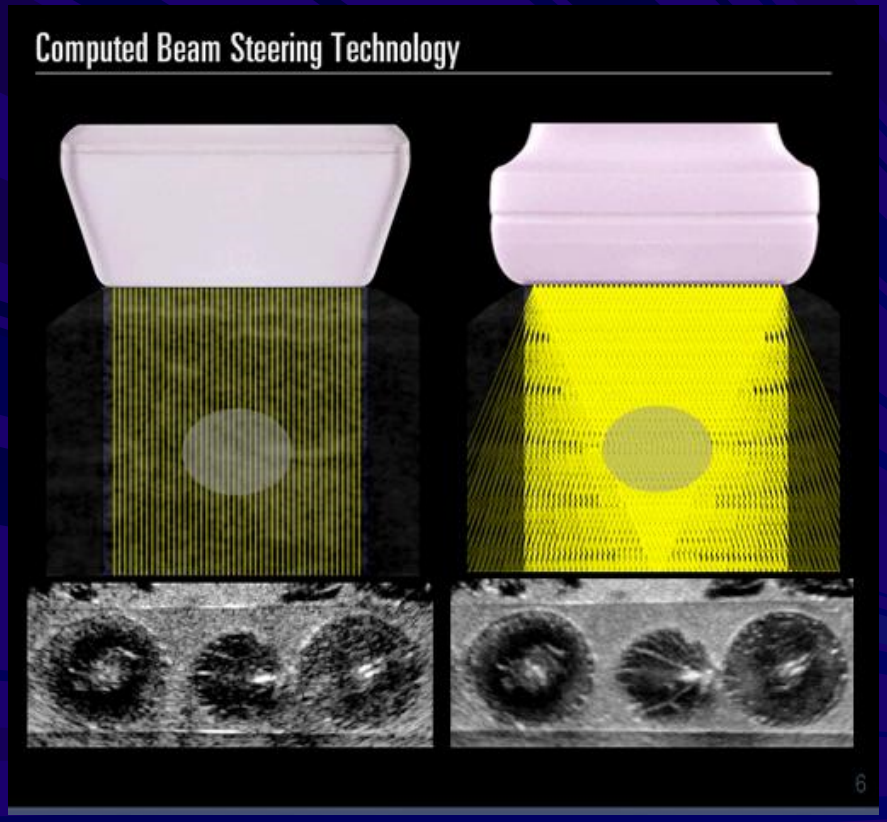
Advances in Technology
Signal Processing

- Image Enhancement
  - Noise reduction
  - Edge sharpening
- Utilization of CT and MRI reconstruction algorithms
  - Beam Steering
  - Spatial compounding

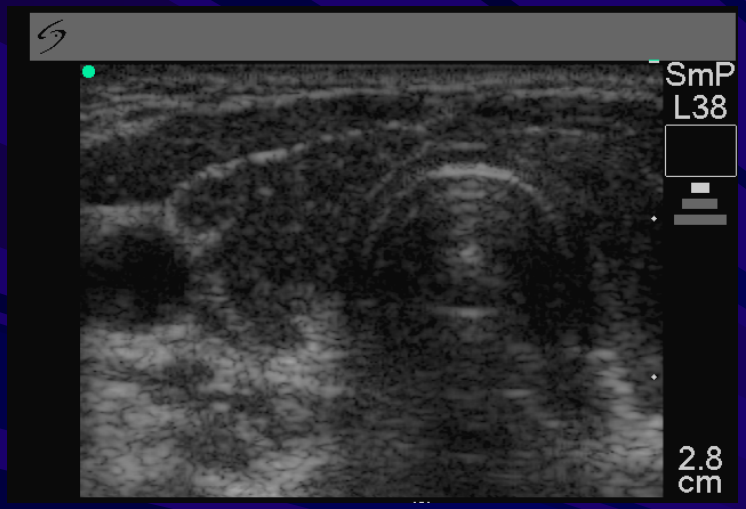
Image Optimization- Compounding

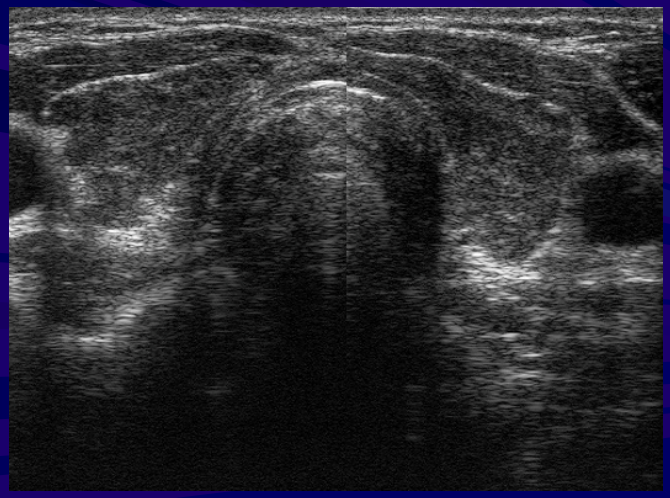


Signal Processing – Compunding

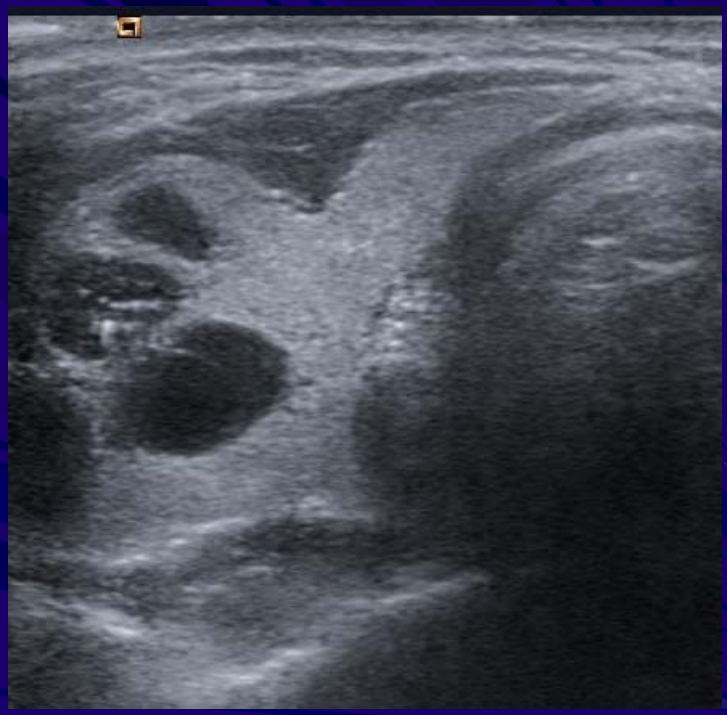


Comparison of standard and processed images



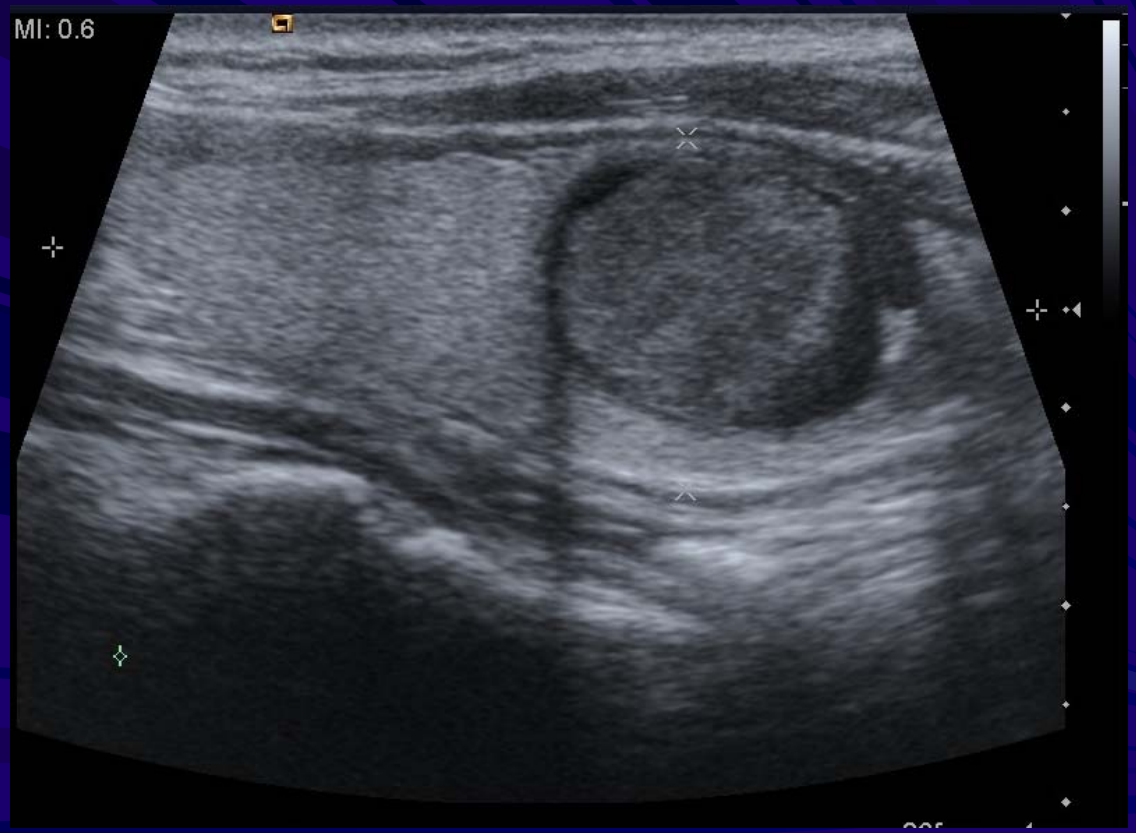


Effect of Compound Imaging on Artifacts



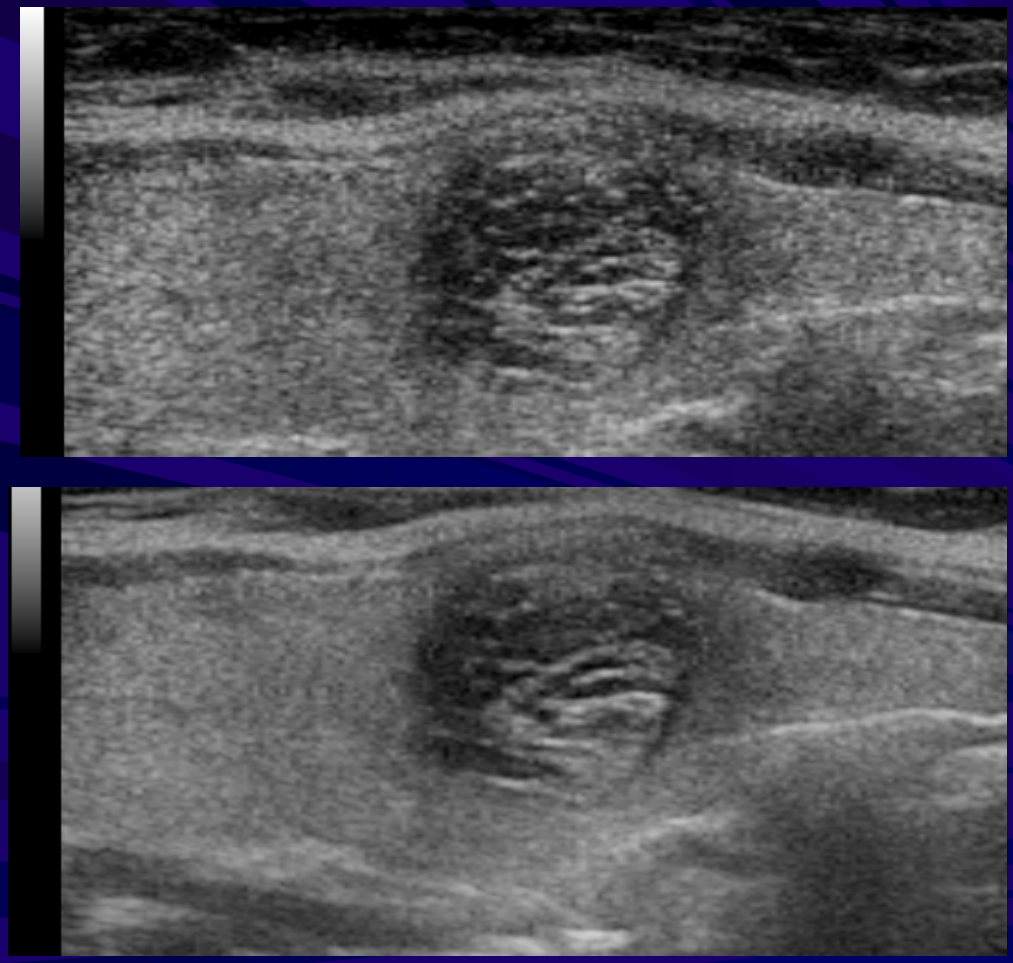
Comet Tails

Effect of Compound imaging on Artifacts

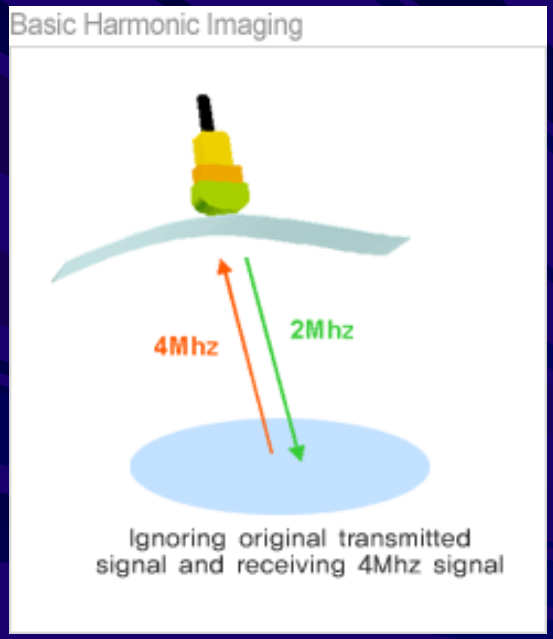


Edge Artifact and Enhancement

Effect of Compound Imaging on Spongiform Nodule



Tissue Harmonic Imaging



At higher power tissue will reverberate and produce harmonics of the original frequency. Selective detection of the second harmonic.

Tissue Harmonic Imaging

- Different tissues will have varying degrees of harmonic generation
- Selective detection of harmonic
  - Higher frequency: Improved resolution
  - Less distance: Less noise
  - Increased contrast

Tissue Harmonic Imaging

- Increased conspicuity
- Improved signal to noise for deeper structures

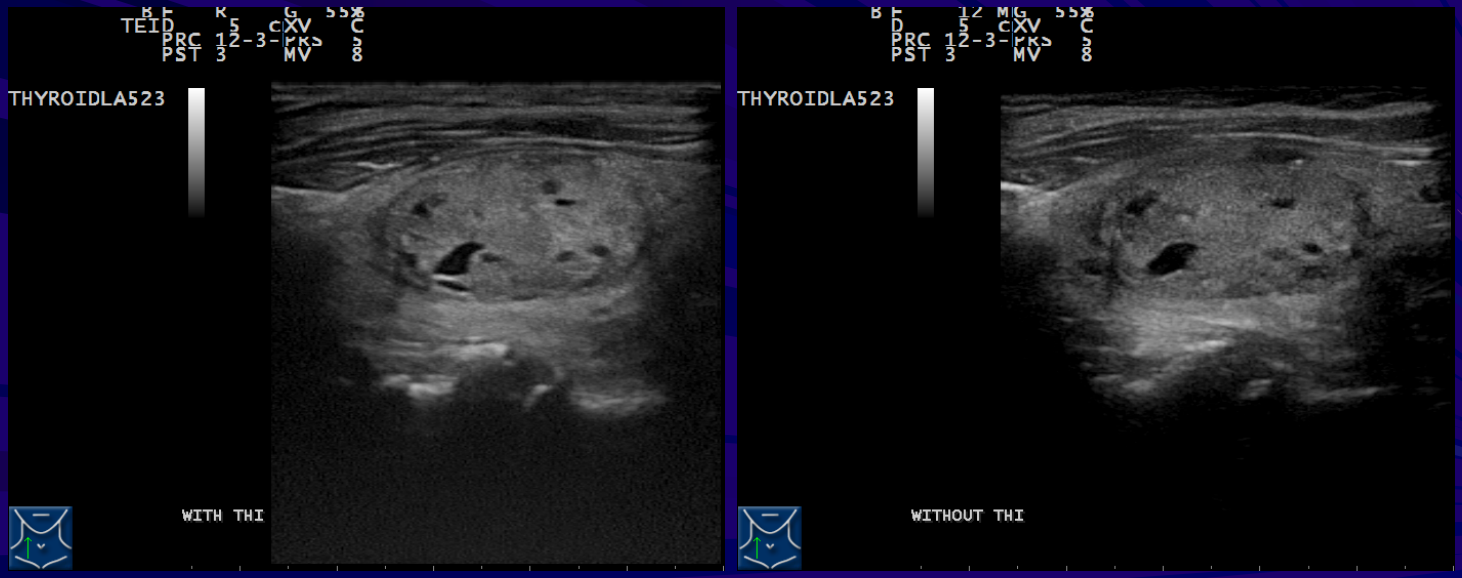
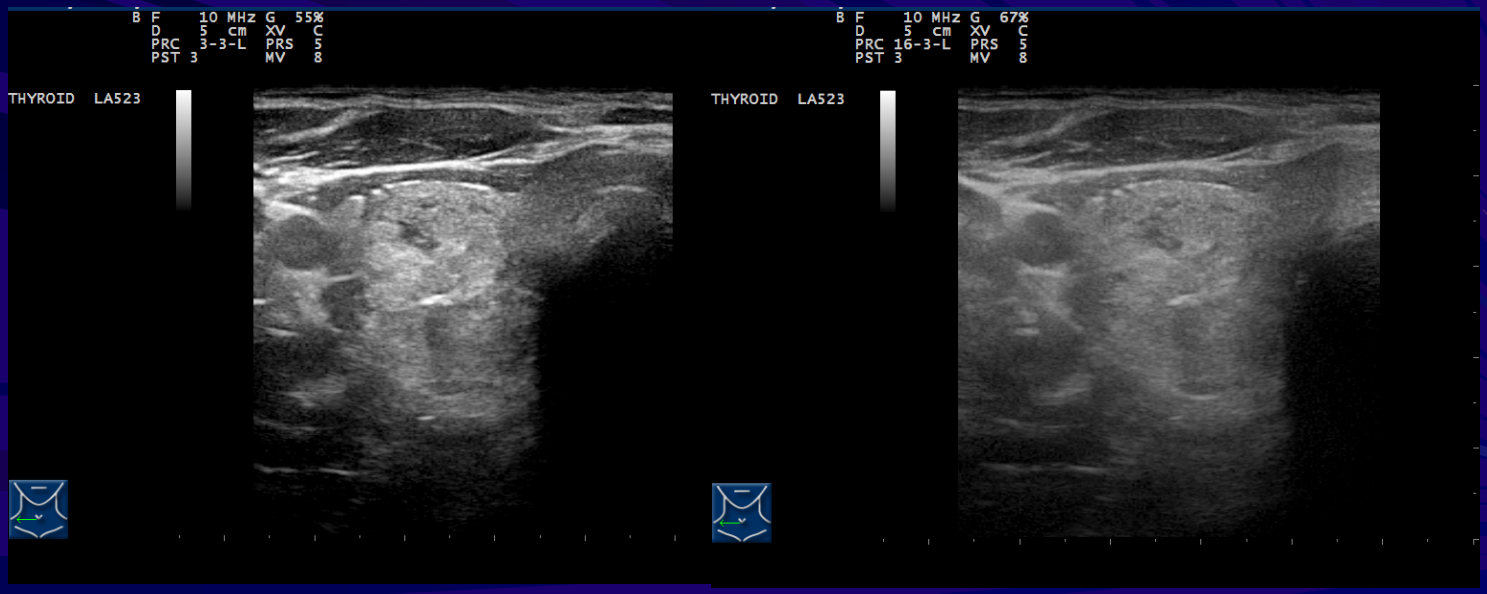
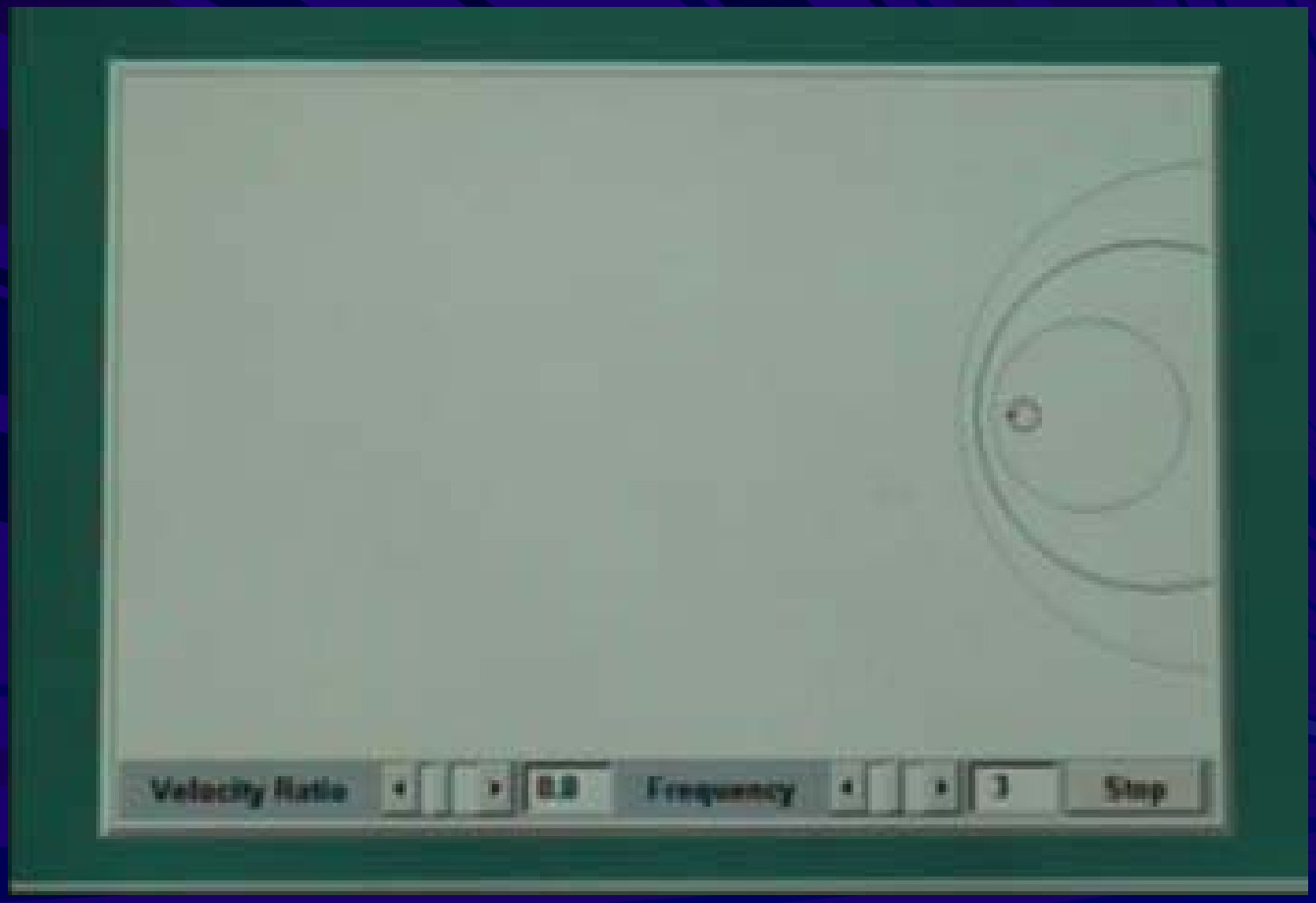


Image Optimization – Dynamic range

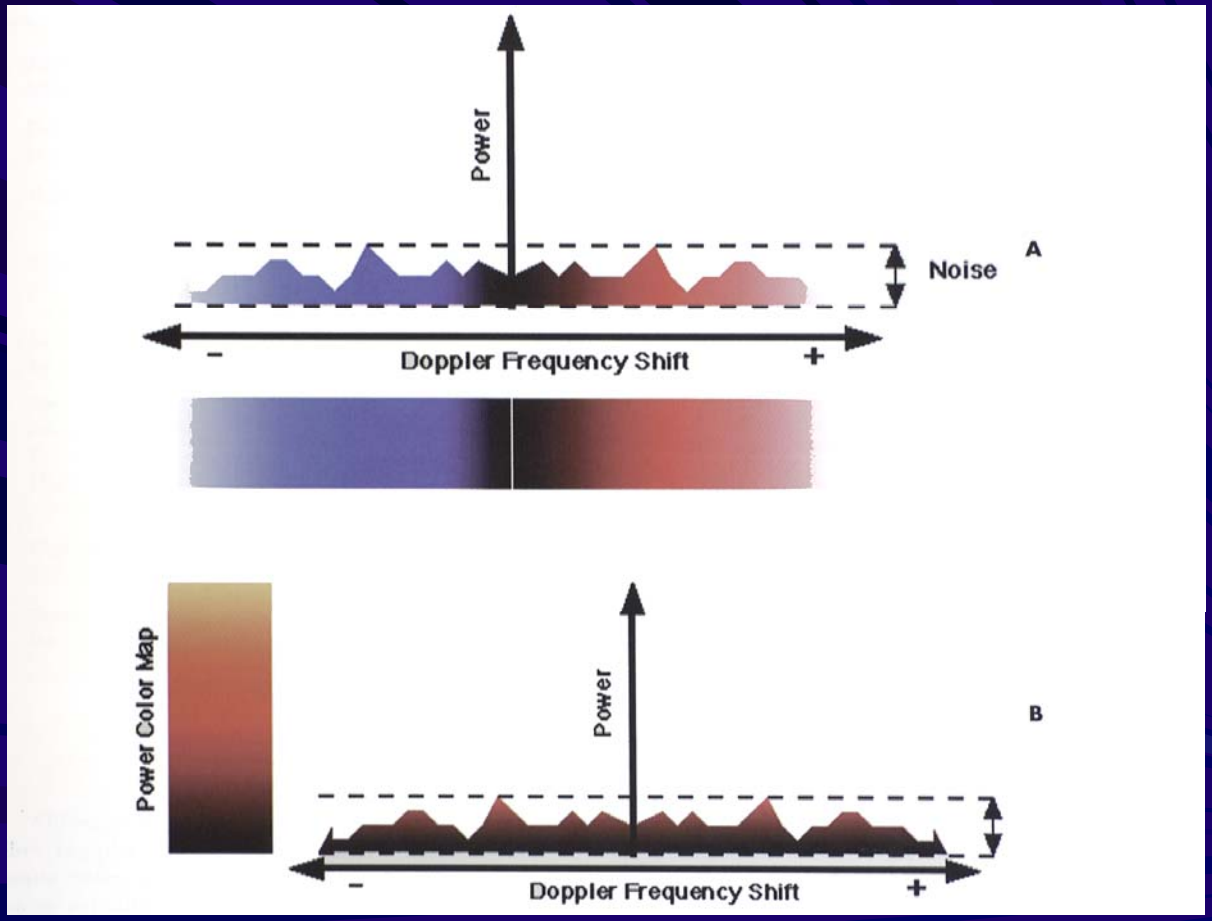
- May increase conspicuity of subtle lesions



Doppler Shift

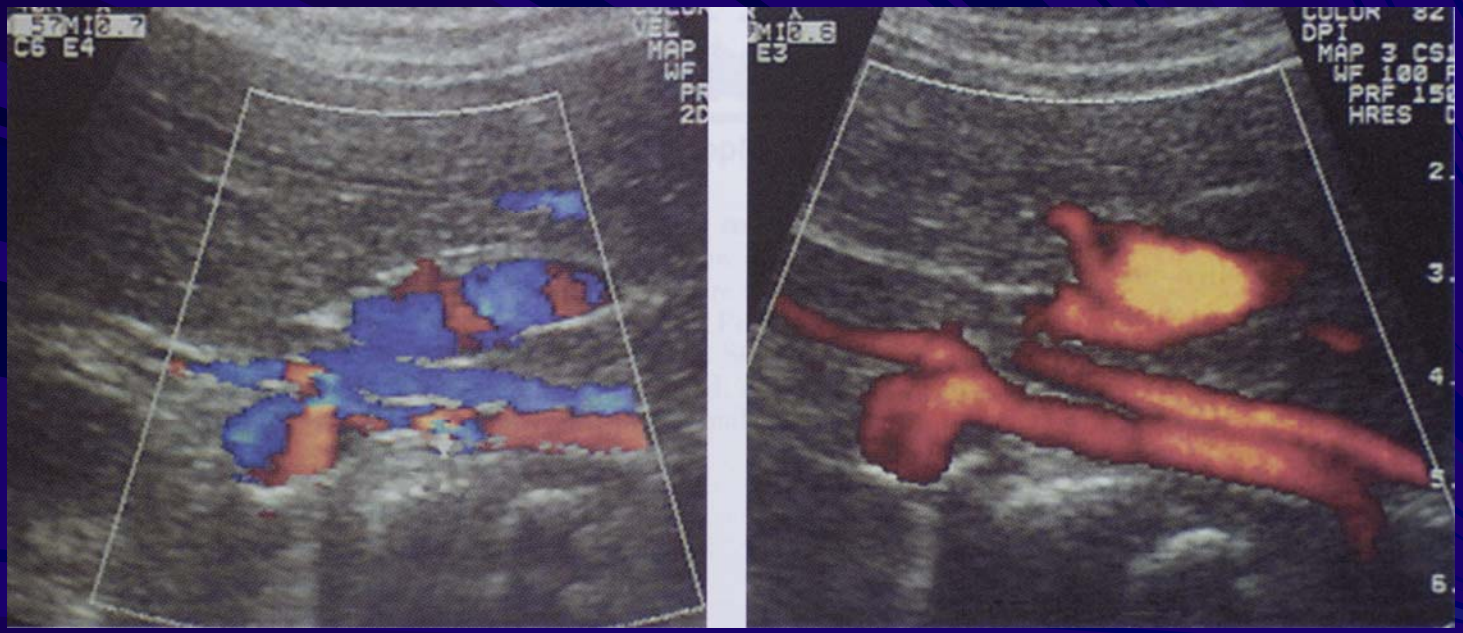


Color and Power Doppler



Meritt, 1998

Color and Power Doppler

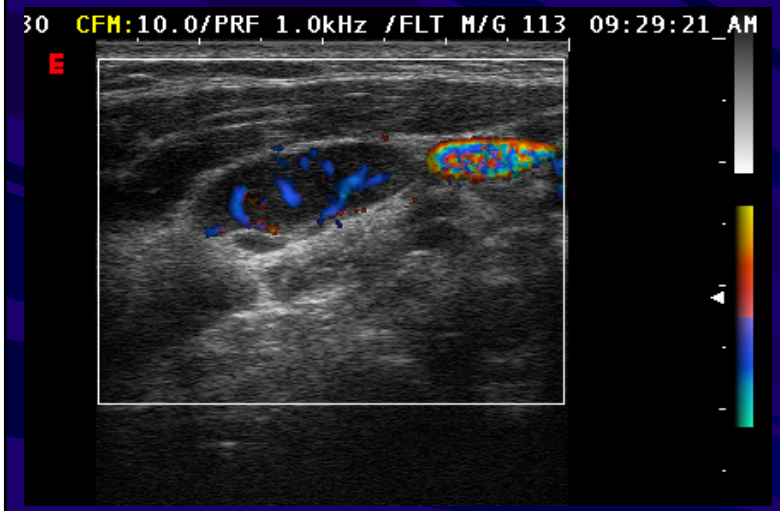


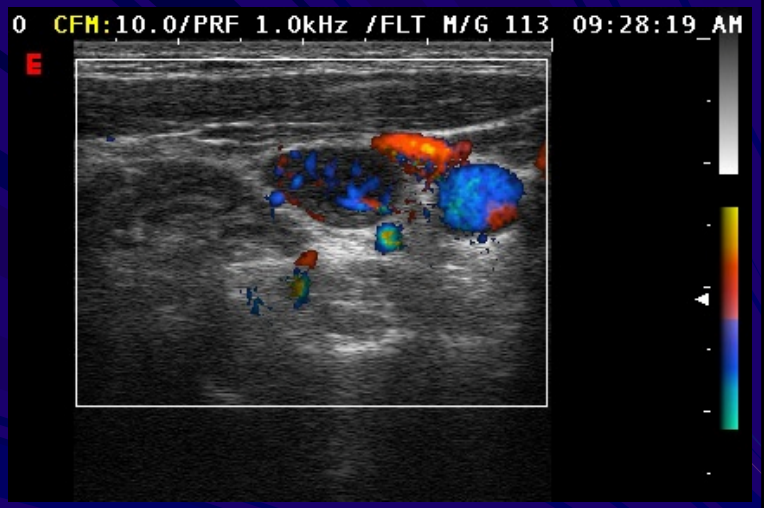
Meritt, 1998

Color and Power Doppler

- Color Doppler
  - Provides information regarding direction and velocity.
  - More useful in vascular studies
- Power Doppler
  - No information regarding velocity
  - Less angle dependence
  - Less noise
  - Increased sensitivity for detection of flow

Doppler – Lymph nodes





In normal nodes vessels enter centrally at the hilus, and spread along the long axis.
In malignant nodes aberrant vessels enter peripherally in the node capsule. Increased (disordered) vascularity may be seen peripherally and centrally.

Doppler of Nodes

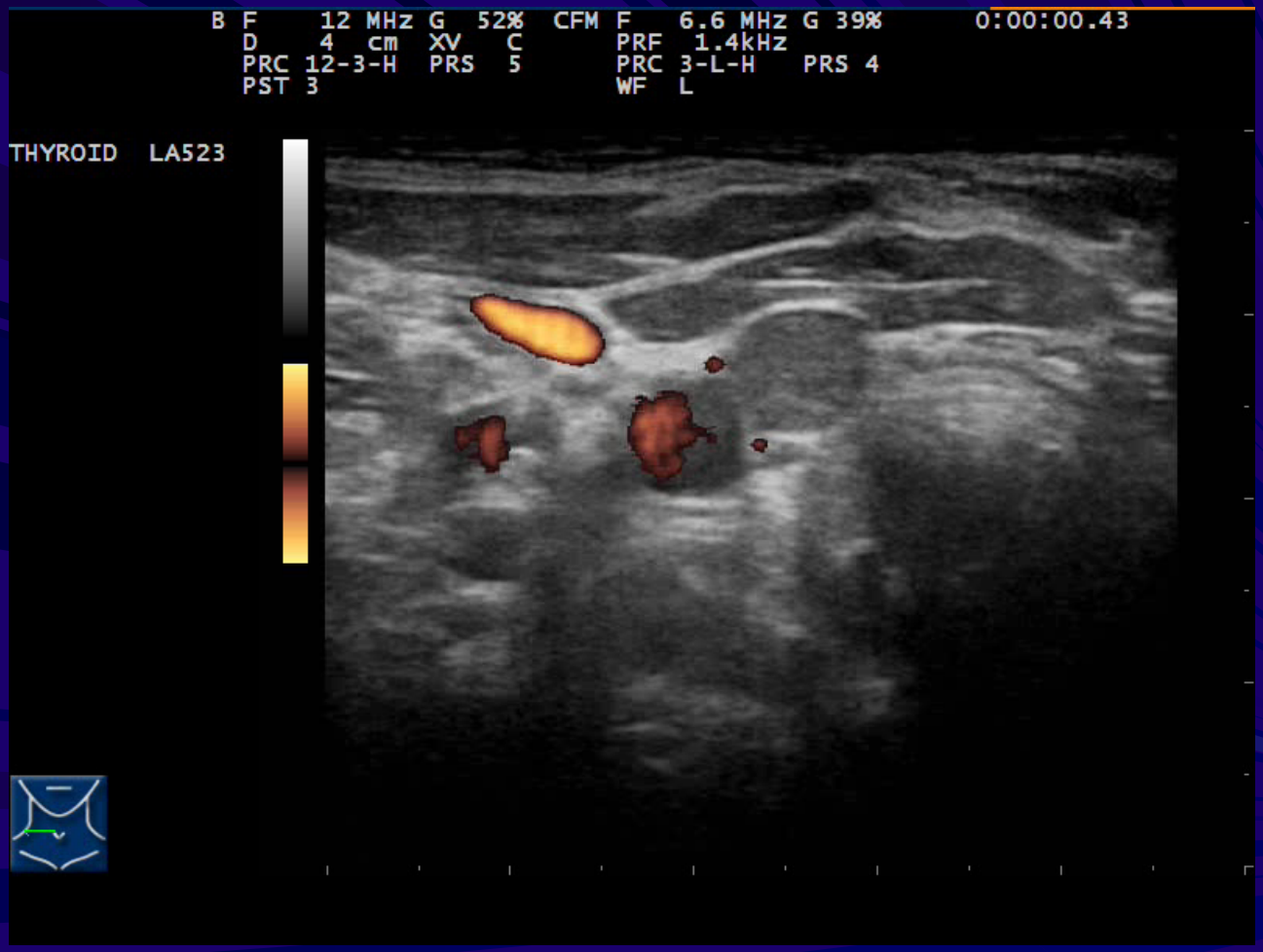
- Demonstration of Chaotic or peripheral vascularity in malignant nodes
  - Can be seen in reactive nodes
- Normal vascularity is reassuring
- Power Doppler for high sensitivity
- Use low wall filter
- Use a low PRF < 800
  - Low wall filter and low PRF both increase the sensitivity for detection of low flow.

Achieving the highest sensitivity with Doppler imaging.

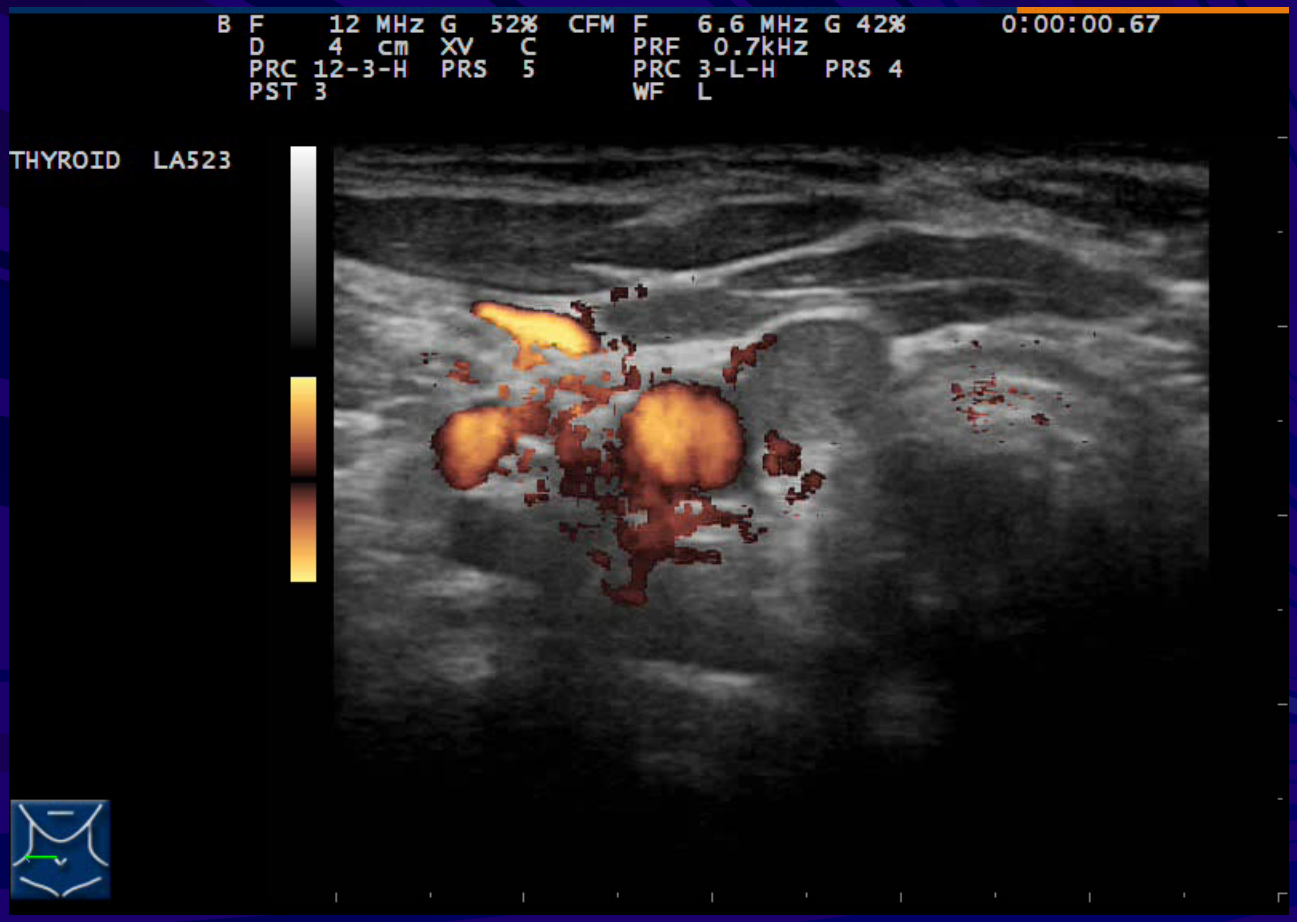
High Doppler sensitivity needed for lymph nodes.

- Power Doppler
- Maximum Doppler gain without noise.
- Low Pulse Repetition Frequency
  - PRF < 800
- Low wall filter.

PRF 1400 → 700



PRF 700 – Wall filter varies



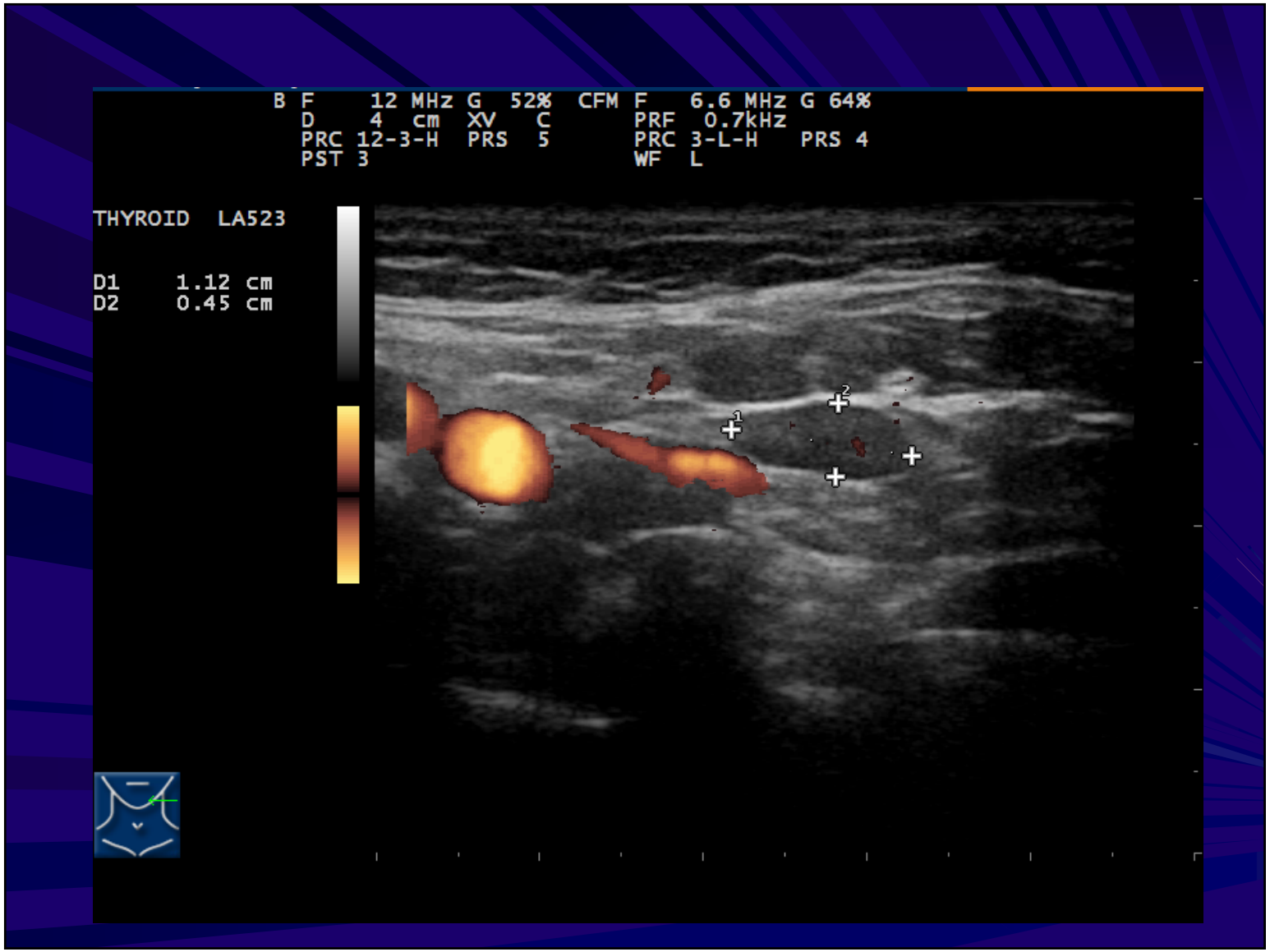


Image Optimization
Summary and Conclusions

- High quality equipment is preferable, BUT a great ultrasonographer using low quality equipment will obtain better images than a lousy ultrasonographer with great equipment.
- "I need to find out what type of piano Mozart played so I can sound like him."
- User adjustments of gain, depth, frequency, focal zones, dynamic range, spatial compounding, pulse repetition frequency, and wall filter will give the optimal image quality.