Physical 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
Optimal Depth
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

AZIMUTHAL (up-down)

AXIAL (distance from transducer)

LATERAL (side to side)
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**

- 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

Near field (Fresnel Zone)
Large variations of intensity

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

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.