Harmonics and Contrast Agents

Chapter 17

What is Harmonics?

- The sound reflections of the fundamental or transmitted frequency that are twice their original frequency.
- It is also referred to as the second harmonics since it is twice that of the fundamental frequency.
- So if a 2 MHz transducer is used what is the harmonic frequency?

Harmonic imaging

- Harmonics result from non-linear behavior of sound.
- Most effective when the fundamental image is poor.
- Harmonics undergoes less distortion.
- Two forms of harmonics important to us are:
  - contrast and tissue

Contrast agents

- Often referred to as microbubbles.
- Encapsulated air that is either swallowed or injected.
- Has a different acoustic interaction than blood or tissue resulting in a very strong reflection.
- To be a good contrast agent it must possess five requirements.

Contrast agents

- Safe
- Metabolically inert
- Long lasting
- Strong reflector when imaged
- Ability to pass through capillaries

Contrast Harmonics

- Produced by the interaction of primary frequency with the contrast microbubbles.
- This harmonics results from the non-linear behavior of the contrast when the sound beam strike them.
Contrast Harmonics

• How is this non-linear behavior created?
• Sound is a pressure wave that creates oscillations.
• When this sound strikes the bubbles it grows and shrinks as a result of the pressure wave.
• Harmonics result from the uneven changes in bubble size as it is exposed to the sound beam.
  – It resonates.

Contrast Harmonics

• When exposed to high pressure the bubble shrinks and the pressure with it increases.
• When exposed to low pressure they will expand.
• This expansion and contraction results in the bubbles changing shapes unevenly.
• Small amounts of energy changed to a harmonic frequency.

Mechanical index

• Used to estimate the amount of contrast harmonics.
• Frequency and pressure dependant.
• Increases lower sound frequency as well as stronger sound waves.

Microbubbles and scattering

• They are strong reflectors.
• They are the size of RBC’s.
• Resonate in the sound range of 2 – 4 MHz.
• Note the similarity in range to that of diagnostic imaging.

Non – linear behaviors

• Is there another form of non-linear behavior of a microbubble that creates contrast harmonics?
  – The relationship between MI and harmonic creation.
• In linear behavior a low MI would provide a weak harmonic.
• A intermediate MI a intermediate harmonic.
• A strong MI a strong harmonic.

Non – linear behaviors

• Low MI sound fails to cause the required contraction and expansion of the bubbles to create harmonics.
• Intermediate MI do create moderate amounts of harmonics.
• High MI create very high harmonics.
Low MI: 0.1

- No harmonics
- Backscatter
- Linear behavior
- High frequency sound
- Low beam strength

MI: 0.1 – 1.0

- Strong harmonics
- Resonance
- Non-linear behavior
- Lower frequency sound
- Higher beam strength

MI: > 1.0

- Strong harmonics
- Bubble disruption
- Extreme non-linear behavior
- Highest beam strength

Things to remember about contrast agents

- The type of shell and gas that fills them
- The shell is what traps the gas and increases the life of the bubbles
- Shells are made to be flexible
- The internal gas determines the stability of the microbubble

Tissue Harmonics

Created during the transmission of sound when the sound wave interacts with the body converting the fundamental frequency one containing one with harmonics as well

What creates tissue harmonics

- The sound wave is a series of compressions and rarefactions
- As sound travels through tissue its speed is slightly uneven
- It travels faster during compression and slower through rarefactions
- This non-linear wave variation in speed creates the tissue harmonics
What creates tissue harmonics

- This variation in speeds alter the shape of the wave (sound beam)
- Energy is transferred to harmonics in a small amount
- As the waves continues in the tissue the wave distorts more creating a stronger harmonic wave
- In essence the deeper the sound travels the stronger the harmonic wave grows

Why is gradual harmonic signal development important?

- Most of the fundamental imaging artifact occurs in the first few cm
  - The beam is very strong
  - Many superficial layers to distort the sound
- Since harmonics does not exist superficially it does cannot distort.

Tissue harmonics

- Sound beam strength and harmonic creation is non-linear
- Weak sound beams don't create harmonics
- Intermediate strength sound create a minimal amount of harmonics
- Strong beams generate significant harmonics

Why is it important that only strong beams create harmonics?

- Grating or side lobes are always present
- They are however weak signals
- Little or no harmonics are created with them
- The primary beam path has the highest signal strength

Why is it important that only strong beams create harmonics?

- This beam is least likely to create artifacts and most likely to create harmonics
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- The harmonic image has less distortion because the harmonic image arises from the non-distorted portion of the beam