Bioeffects

Chapter 22

Bioeffects

• Most energy produced by the ultrasound transducer remains in the body
• Instruments used to test sound energy are used mostly by scientists or engineers and not clinical personnel.
• A hydrophone is used to measure the acoustic pressure in the sound beam

Hydrophone

• Varying the position of the hydrophone one can determine the actual shape of the beam
• types of measurements performed
  – Period, PRF, PRP, and pulse duration
• since this instrument can be calibrated sound intensities and output measurements can be determined
• acousto-optics is an interaction of sound and light creating a shadow called Schlieren allowing us to actually see the shape of the beam in a medium

Radiation force

• Since the sound beam has a force related to it as it strikes an object it can be measured
• Utilizing an instrument that absorbs this force one can determine the power of the sound beam created by the transducer

Absorption

• Method used to measure sound output of transducers by the conversion into heat
  – Calorimeter
  – Thermocouple
  – Liquid crystals
<table>
<thead>
<tr>
<th>Calorimeter</th>
<th>Thermocouple</th>
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</thead>
<tbody>
<tr>
<td>- Measures the power of the entire beam through absorption</td>
<td></td>
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<tr>
<td>- Calculated by measuring the temperature rise at the time of heating</td>
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<tr>
<td>- Measures the power in a particular location in the beam</td>
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<tr>
<td>- It is a tiny electronic thermometer with a small amount of absorbing material on it.</td>
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<tr>
<td>- When placed within the beam the temperature rise relates to the power at that location</td>
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<table>
<thead>
<tr>
<th>Liquid crystals</th>
<th>Ultrasound imaging risk benefit relationship</th>
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<tbody>
<tr>
<td>- Is a material that changes color based on temperature</td>
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<tr>
<td>- As the beam is absorbed by the material the temperature of the material rises</td>
<td></td>
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<tr>
<td>- This rise changes the color of the material</td>
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<td>- Provides information about the shape and strength of the beam</td>
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<tr>
<td>- The benefits of having the exam must outweigh the risks of the exam</td>
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<tr>
<td>- As related to fetal diagnostic imaging there has as of yet been no confirmed harm caused by ultrasound imaging</td>
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<tr>
<td>- Low intensity sound has no known bioeffects</td>
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<tr>
<td>- Very high sound intensities can damage tissues but these intensities exceed standard imaging intensities</td>
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<tr>
<td>- Therapeutic ultrasound is an example of a controlled use of beneficial bioeffects</td>
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<table>
<thead>
<tr>
<th>Dosimetry</th>
<th>Areas of Research</th>
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<tr>
<td>- A scientific way of measuring and identifying the characteristics of a US beam's potential for producing biological effects</td>
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<tr>
<td>- No effects have been found, research is continuing to study the possibilities</td>
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<tr>
<td>- In vivo - research performed within the body</td>
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<tr>
<td>- In vitro - research performed outside the body - provides opportunities to do research impossible to do on living subjects – shows very high intensities can cause genetic damage and cell death</td>
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</table>
## AIUM Statement on In Vitro Bioeffects

- This research is important
- While in-vitro bioeffects are real they may not apply in diagnostic settings
- Any claim stating a direct effect (without in-vivo validation) should be viewed with trepidation


- Includes “prudent use” of diagnostic ultrasound outweighs the risks, if any, that may be present.
- Strongly discourages the non-medical use of ultrasound for “psychosocial or entertainment purposes”.

## Types of studies

- Mechanical approach
  - searches for any relationship between cause and effect
- Empirical approach
  - searches for relationships between exposure and response
- While both have merit the strongest conclusion is make when both are in agreement

## Mechanisms of Bioeffects

- There are two mechanisms that can result in bioeffects and are important to understand
  - Thermal effects
  - Cavitation

## Thermal Mechanism

- Bioeffects may result from tissue temperature elevation
- Remember as sound travels through the body sound energy is converted to heat.
- The body's core temperature is 37°C and does not necessarily function appropriately outside this point

## ACOUSTIC OUTPUT LABELING STANDARD

- **Thermal index** - gives the maximum temperature rise in tissue that can be predicted as a result of a diagnostic exam. It is the ratio of the in situ (threshold) acoustic power to the acoustic power to raise tissue temp. by 1 degree C. **THIS IS A NUMBER AND HAS NO UNITS**
  - A. TIS = soft tissue (abdominal)
  - B. TIB = bone is at or near the focus of the beam
  - C. TIC = cranial bone is at or near the focus of the beam (pediatric & adult)

  *Note: the power required cause a 1 degree C temp. rise in bone is less than tissue because energy absorption by bone is higher.*
Thermal Mechanism
Empirical findings

- Prolonged elevation of body temperature results in serious tissue damage
- Tissue heating is related to output
- Infertility can result with a 2° to 4° rise in testicular temperature
- A likelihood of harmful effects may result from a combination of exposure time and temperature

Thermal Mechanism
Empirical findings

- SPTA intensities of the beam is related to the maximal heating effect
- More energy is absorbed by bone than soft tissue.
- Fetal tissue is not as tolerant as adult tissue – defects have resulted from elevated temperatures
- No effects reported with exposures >50 hrs and temperature up to 2°C

Thermal Mechanism
Mechanistic data

- Models seem to correlate with experimental data even though:
  - the sound beam is so complex
  - the equipment very diverse
  - tissue characteristics are different

PRIMARY MECHANISMS OF BIOLOGIC EFFECT PRODUCTION

Cavitation mechanisms- what is “CAVITATION”?
- The dynamic behavior of microbubbles in the media which is exposed to ultrasound.
- These bubbles are known as Gaseous nucli
- Cavitation can also be described as the creation of Gaseous nucli from gases dissolved in a fluid

There are two types of cavitation:
- Stable
- Transient

BIOEFFECT PRODUCTION

- Stable cavitation-
  At low MI levels microbubbles already in the media expand & contract in response to pressure changes as the sound travels through the media.
  They might double in size but they do not burst

BIOEFFECT PRODUCTION

- Stable cavitation-continued
  the acoustic energy is intercepted by the bubbles and absorbed.
  Cells are exposed to shearing stresses while the fluid surrounding the cells undergo microstreaming
**BIOEFFECT PRODUCTION**
- **Transient cavitation**: at high MI levels a more violent form of cavitation in which short-lived microbubbles undergo large size changes over a few acoustic cycles then bubbles collapse. Collapsing bubbles produce shock waves, high temperatures and pressures resulting in decomposition of water to free radicals, and other chemical reactions. Only a 10% increase over stable cavitation is needed.

**ACOUSTIC LABELING STANDARD**
- **Mechanical index**: describes the likelihood of cavitation.
  - No adverse effects caused by this have been observed in humans at typical diagnostic output levels.
  - BOTH INDECES REPRESENT WORST-CASE SCENARIOS. THEY ARE RISK INDICATORS.

**Mechanical index**
- MI is related to peak negative pressure and frequency
- Additional negative pressure and lower frequencies create a greater likelihood of a higher MI and cavitation

**Epidemiology**

**Limitations**

**Prospective and Randomized Studies**
ELECTRICAL & MECHANICAL HAZARDS

• Patients are susceptible to electrical hazard.

• Equipment components that could present a hazard:
  - external cables—look for broken insulation
  - damaged probes—DO NOT USE
  - AC (110v) plug should be 3-pronged—if a prong is loose or missing
  DO NOT USE INSTRUMENT

Safety considerations

METHODS OF REDUCING EXPOSURE:

• Use the lowest acoustic power levels to permit adequate penetration
• Master gain or TGC should be used first to increase image brightness
• Shorten exposure times.
• Never do studies without valid medical reasons