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Therapeutic Modalities: Ultrasound

Scott Cheatham, PhD, DPT, OCS, ATC, CSCS

- **Presenter Disclosure:** Financial: Scott Cheatham has received an honorarium for presenting this course. Non-financial: Scott Cheatham has no relevant non-financial relationships to disclose.

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Scott Cheatham
PhD, DPT, OCS, ATC, CSCS

Dr. Scott Cheatham is an Associate Professor in the Division of Kinesiology at California State University Dominguez Hills in Carson, California. He is the owner of Sports Medicine Alliance (SMA). Dr. Cheatham received his Doctor of Physical Therapy (DPT) and his Doctor of Philosophy (PhD) in Physical Therapy. Dr. Cheatham is a Board Certified Orthopedic Physical Therapist (OCS) and a Certified Athletic Trainer (ATC). He also holds several fitness certifications and is a certified ergonomic specialist.

Dr. Cheatham is a national presenter for various organizations and has authored over 100 peer-reviewed publications, textbook chapters, and several home study courses on the topics of orthopedics, health & fitness, and sports medicine. Dr. Cheatham's professional responsibilities include being an associate editor for the NSCA Strength and Conditioning Journal, Journal of the Canadian Chiropractic Association, and a manuscript reviewer for several other peer-reviewed journals.

Dr. Cheatham is an education and research consultant for various health and fitness organizations. His research interests include myofascial interventions and the efficacy of interventions for various musculoskeletal pathologies. His current clinical practice includes sports medicine services, general orthopedics, and sports-performance training.

Learning Outcomes

As a result of this course, participants will be able to:

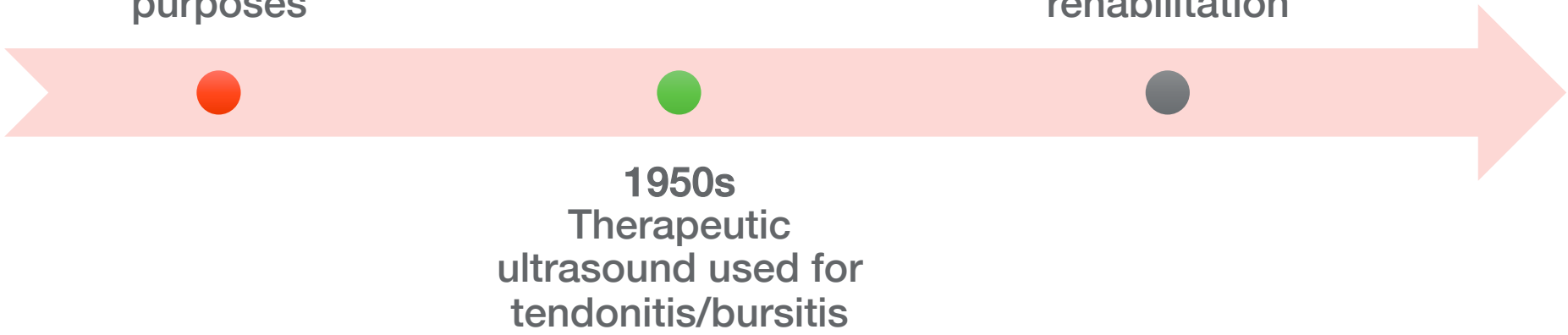
- Discuss the scientific and physiological principles behind therapeutic ultrasound.
- Discuss best practices for administering therapeutic ultrasound (U.S.) for different musculoskeletal conditions.
- Discuss indications, precautions, contraindications, and adverse events for therapeutic ultrasound.

Agenda

- Module 1: Basic Science
- Module 2: Indications and Contraindications
- Module 3: Treatment Parameters
- Module 4: Treatment Application
- Module 5: Ultrasound Research
- Module 6: Device Hygiene
- Module 7: Documentation

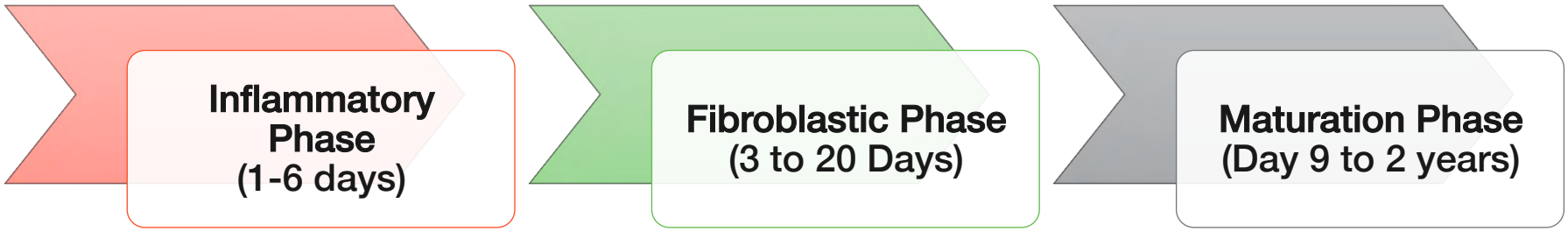
Module I: Basic Science

History of Therapeutic Ultrasound



Miller DL, Smith NB, Bailey MR, et al. Overview of therapeutic ultrasound applications and safety considerations. *J Ultrasound Med.* 2012;31(4):623-634.

Phases of Tissue Healing



Things for the Occupational Therapist to consider!

- When is the optimal time to use U.S. during a patient's rehabilitation program.
- How will U.S. enhance the tissue healing process and the patient's overall recovery.
- The optimal sequencing of interventions (including U.S.) in the patient's rehabilitation program.

What is therapeutic ultrasound?

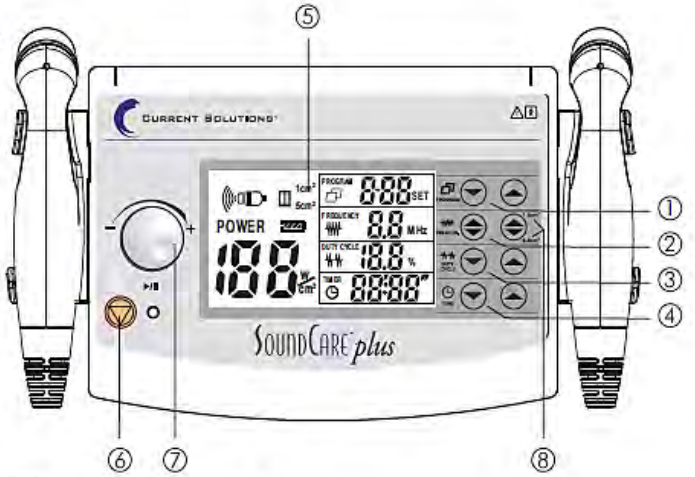
Cameron MH, Sutkus A. *Physical Agents in Rehabilitation - E Book: An Evidence-Based Approach to Practice.* Elsevier Health Sciences; 2017.

CONTINUED

Therapeutic Ultrasound Device

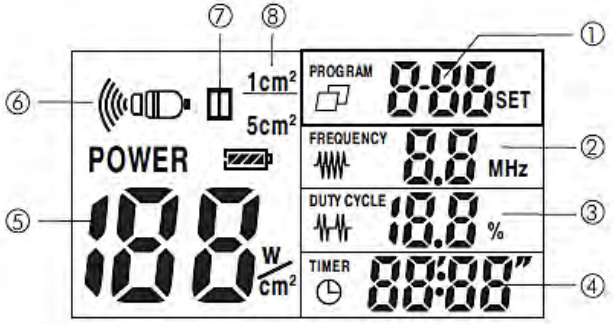
PRESENTATION

Presentation of the device



1) Program adjustment button
2) 1MHz and 3MHz adjustment button
3) Duty cycle adjustment button
4) Timer adjustment button
5) Liquid crystal display
6) Stop button
7) Output intensity adjustment knob
8) Treatment head select button

Liquid crystal display



1) Program indicator
2) Frequency indicator
3) Duty cycle indicator
4) Timer indicator
5) Output intensity/power
6) Ultrasound output indicator
7) Pause indicator
8) Treatment head type

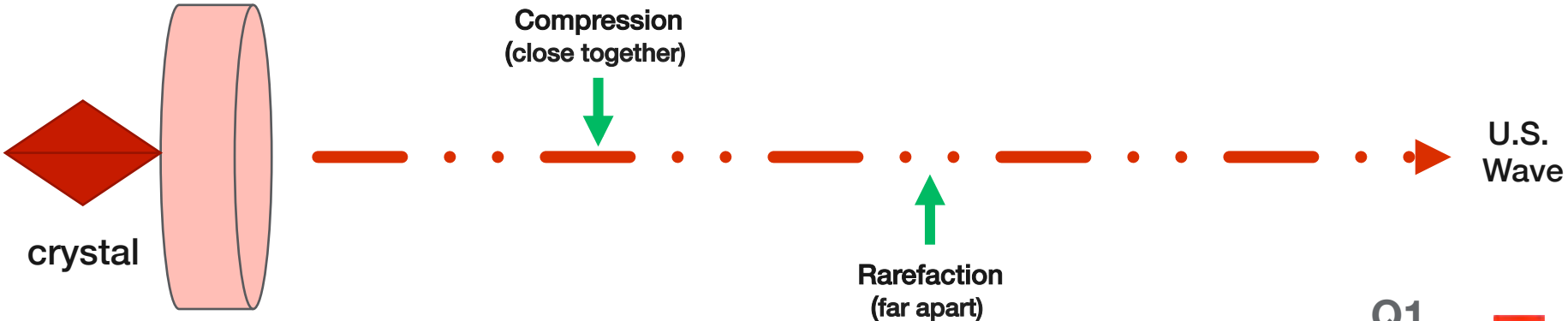
Therapeutic Ultrasound Device

Soundhead: 1cm

Soundhead: 5cm

Therapeutic Ultrasound

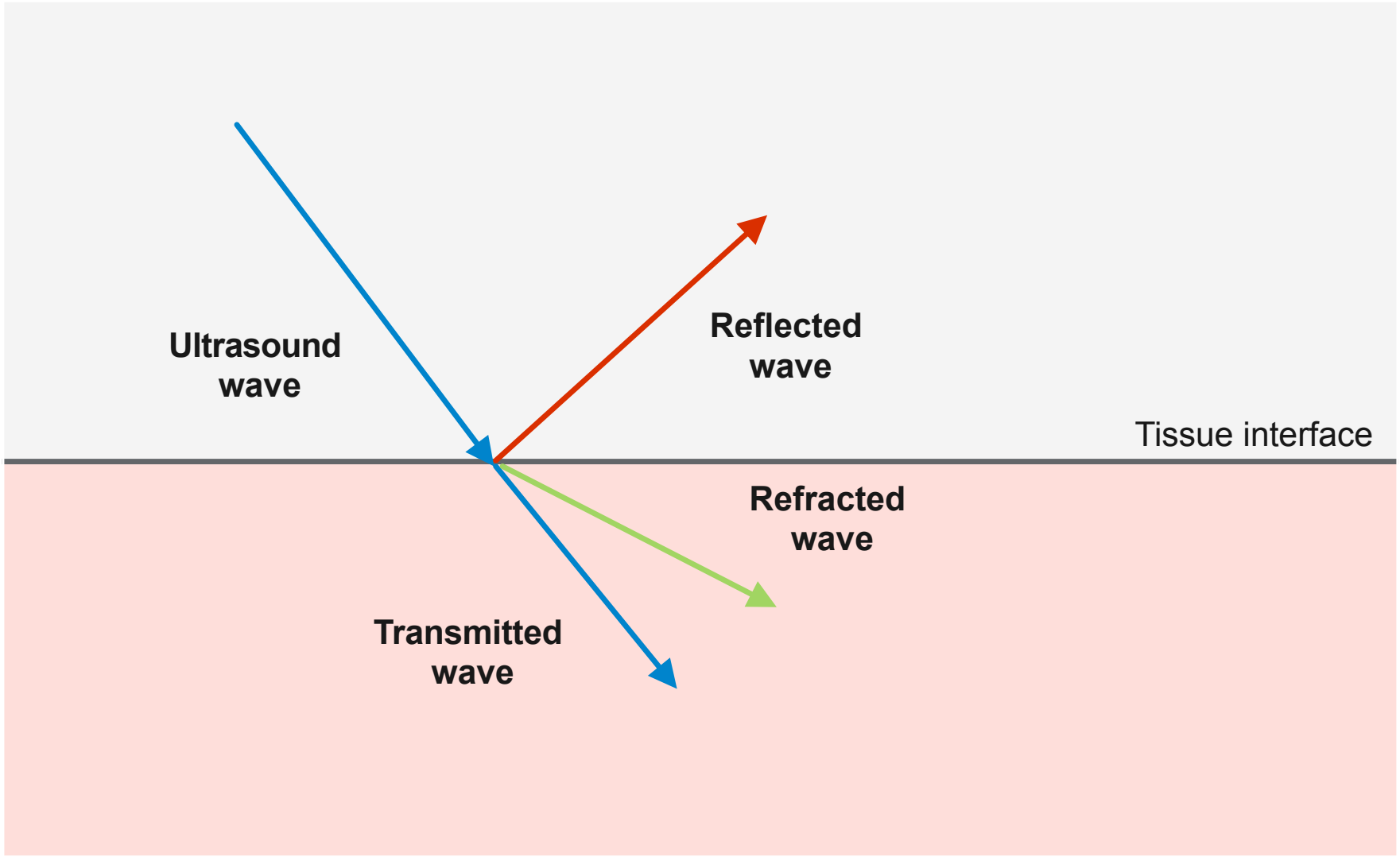
- Therapeutic ultrasound (U.S.): High frequency sound wave used to induce a biological response (> 20,000 Hz).
- Piezoelectric sound crystal:
  - The transducer (applicator) has a crystal inside that creates the wave.
  - AC electrical current to crystal = crystal expands and retracts (vibration)
  - Changes in crystal = compression and rarefaction of wave
  - Conversion of electrical to mechanical energy = U.S. wave



Q1

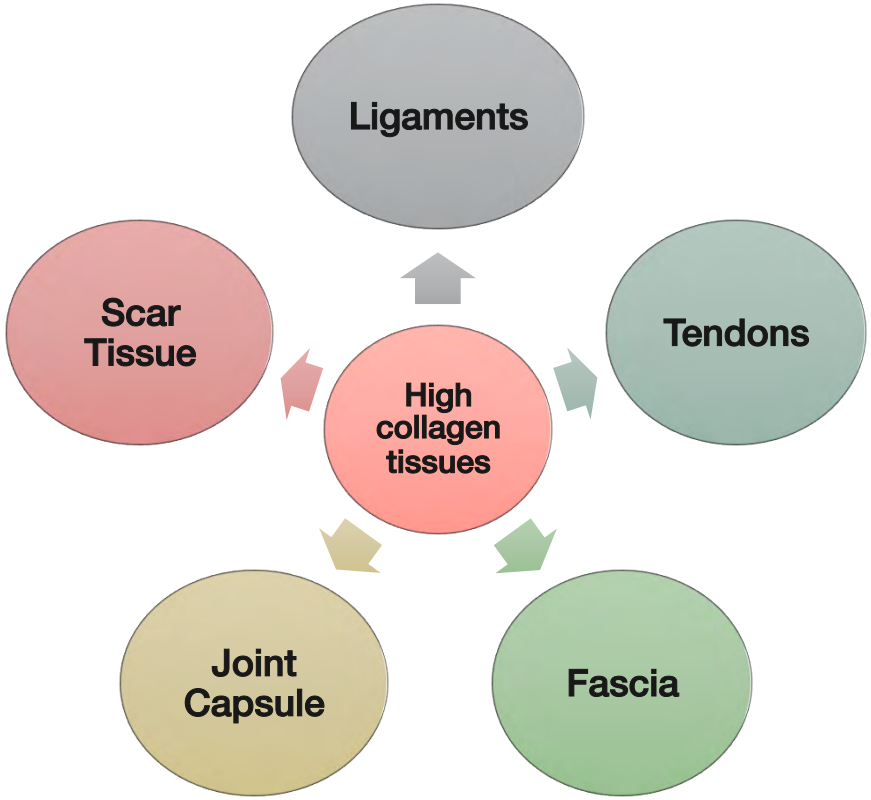
Ultrasound Physics

Attenuation: reduced energy as it passes through different body tissues

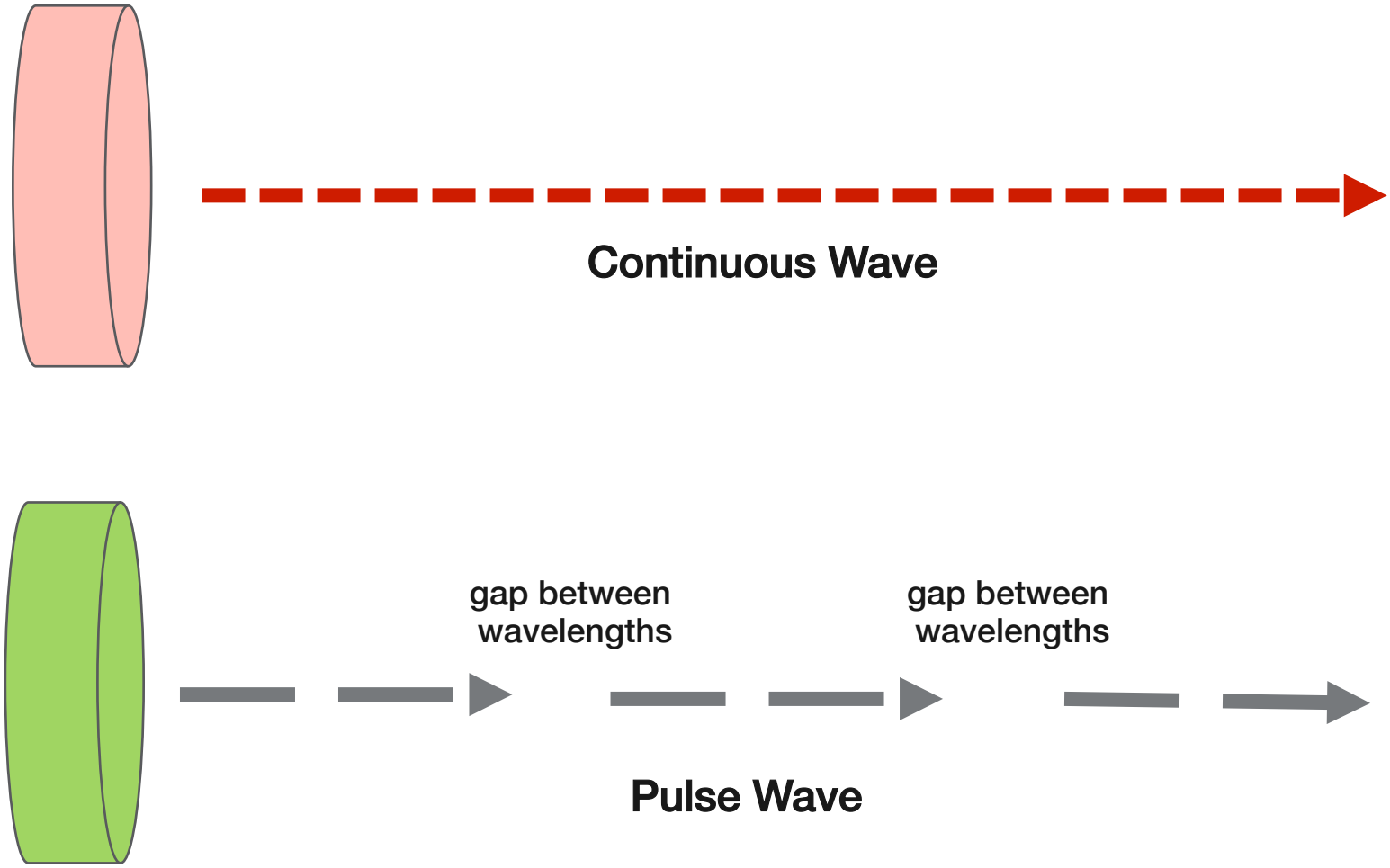


Ultrasound and the Body

- Tissue absorption- more energy is absorbed in the superficial tissues.
  - High collagen tissues absorb the most energy
  - *Bone and cartilage may reflect the energy



Types of Ultrasound Waves

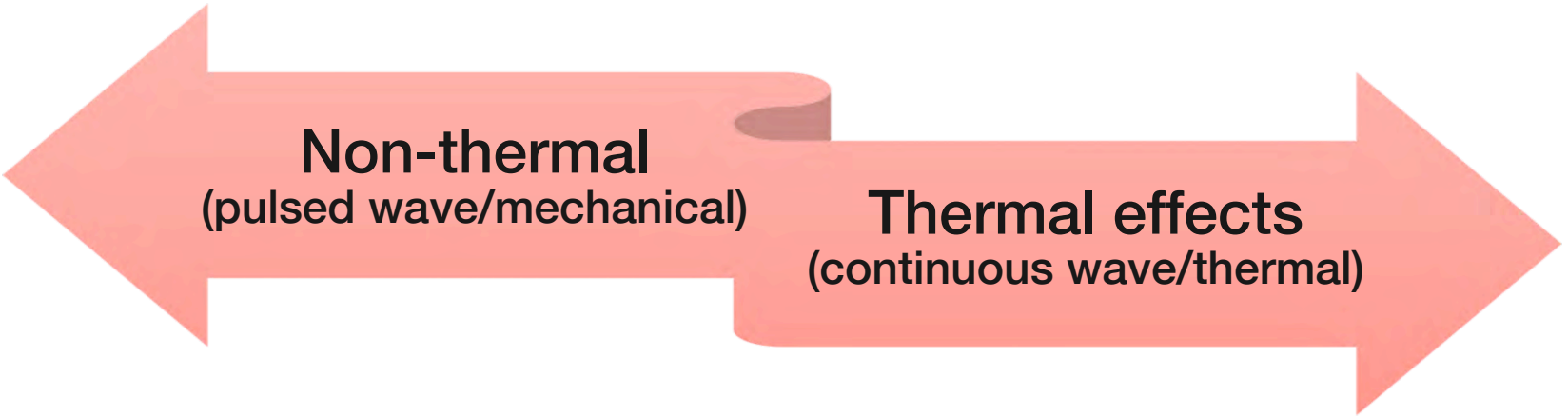


Therapeutic Ultrasound

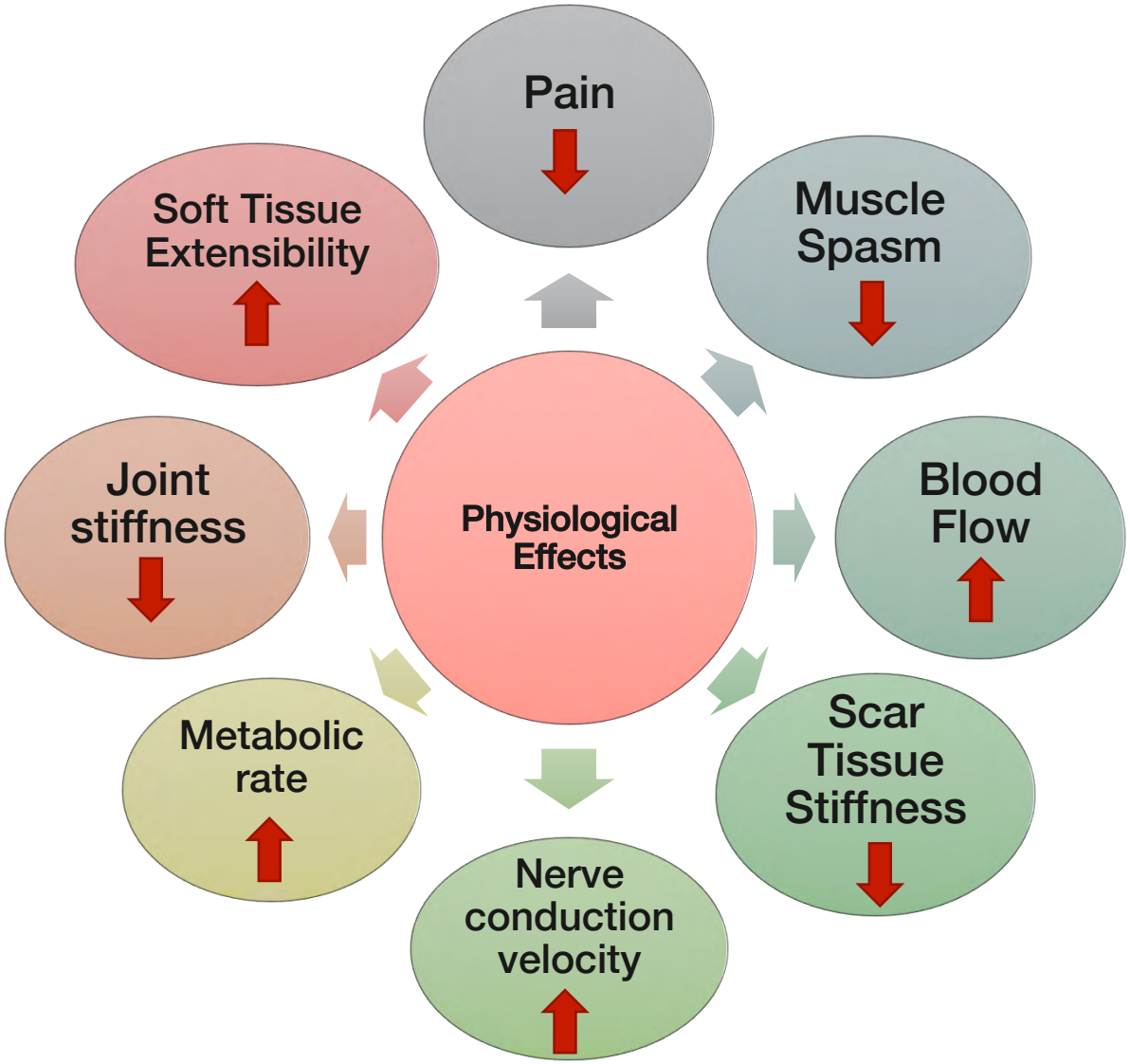
- Continuous (Thermal)
  - Increased tissue temperature
    - Affected by intensity, frequency, and tissue type
- Pulsed (Non-Thermal)
  - Cavitation: Vibration of gas bubbles
    - Stable = change in cell function, Unstable = tissue damage
  - Acoustic streaming: Movement of fluids along the boundaries of cell membranes
    - Increased fibroblastic activity, intracellular calcium
    - Alterations in cell membranes activity and wall permeability
    - Increased protein synthesis

Ultrasound Physics

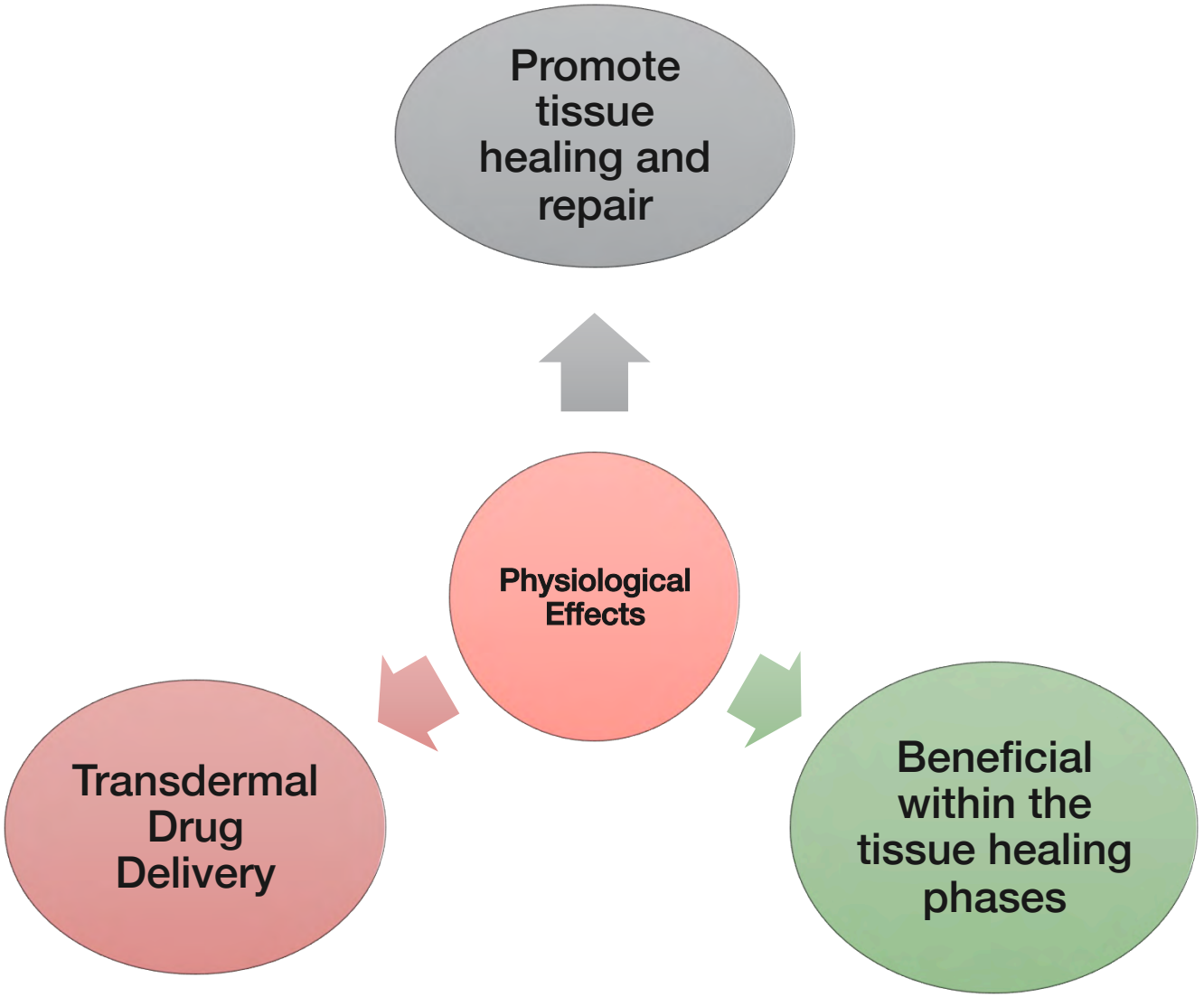
- Mode of heat transfer: Conversion (non-thermal energy to heat)
  - Reflection
  - Refraction
  - Transmission



Ultrasound (continuous/thermal)



Ultrasound (pulsed/non-thermal)



Conducting Media

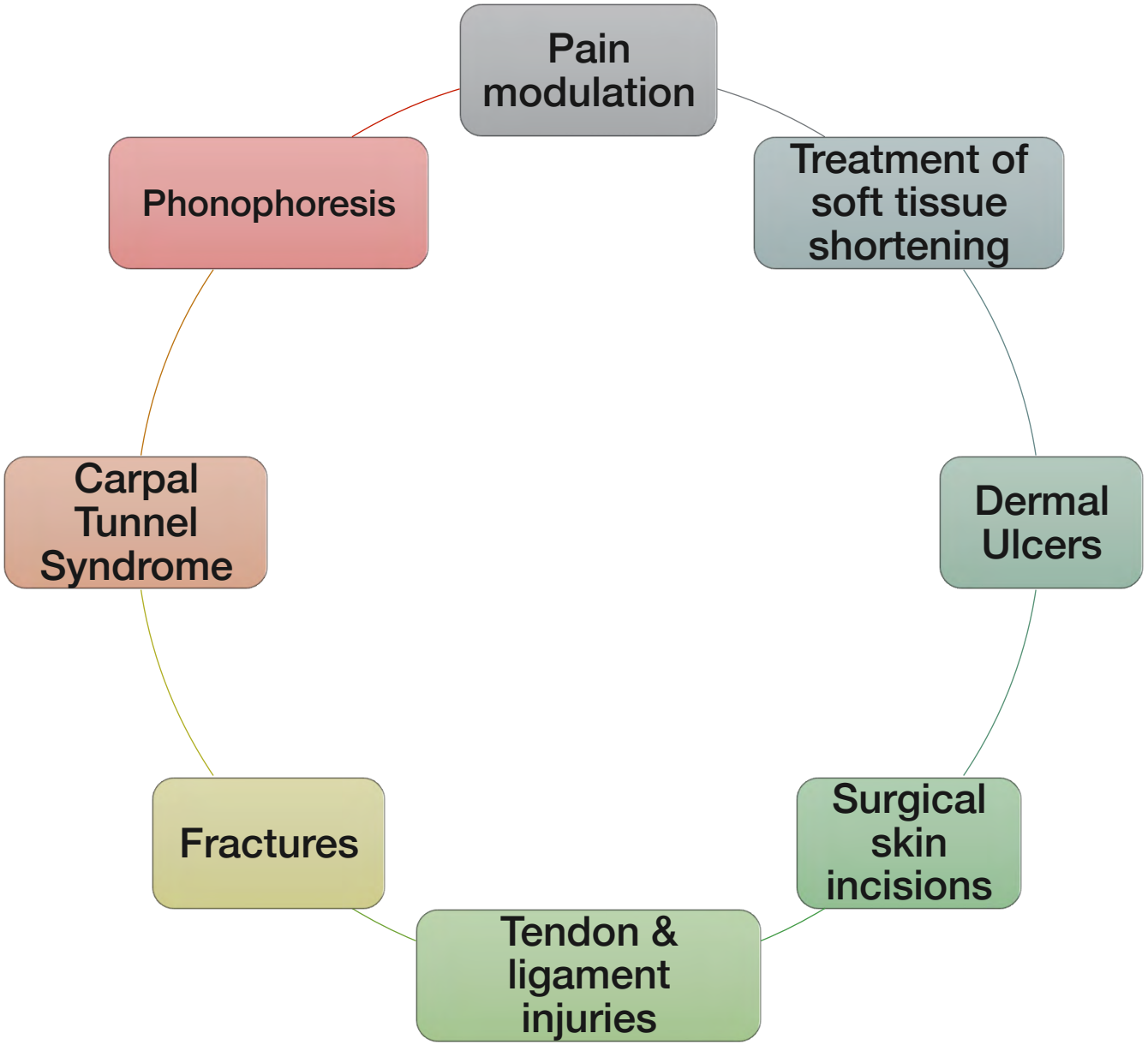
- Air is a poor conductor of ultrasound energy
  - Conduction medium needed to maximize delivery to tissues
    - Ultrasound gel
    - Gel pads
    - Mineral oil/cream
    - Lotions
    - Water immersion (avoid metal containers)

Bottom Line

- Occupational Therapist considerations:
  - Ultrasound transfers energy by conversion.
  - Ultrasound creates thermal and non-thermal effects.
  - High collagen tissues absorb U.S. energy more than bone or cartilage.
  - A medium is used to assist in the transfer or ultrasound energy into the body tissues.

Module II: Indications and Contraindications

Clinical Indications



Precautions & Contraindications

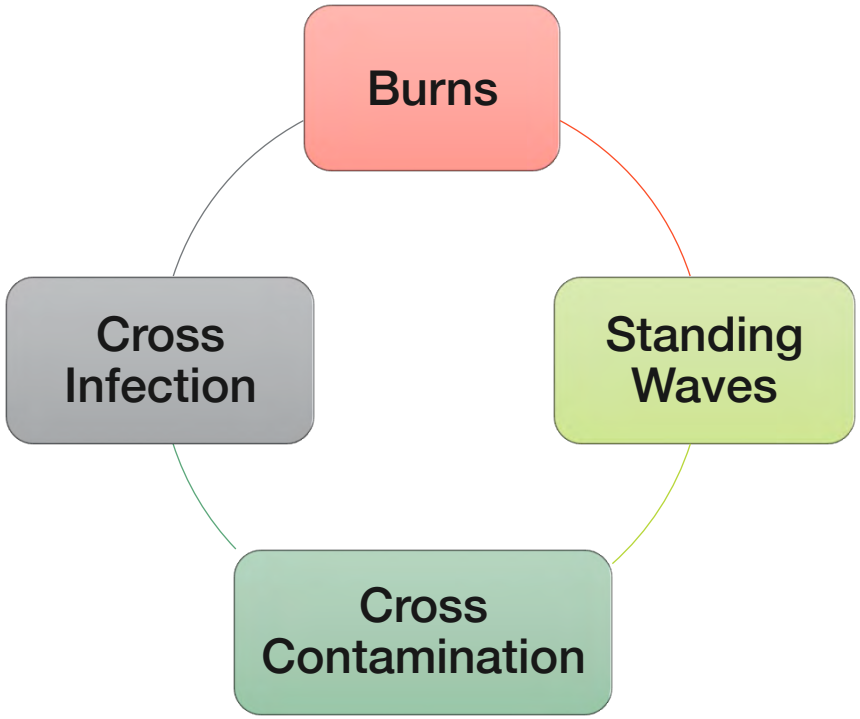
Precautions

- Acute Inflammation
- Epiphyseal plates
- Fractures
- Breast implants
- Poor mentation

Contraindications

- Pregnancy
- Malignancy
- Nerves, veins, and eyes
- Joint cement and plastic
- Thrombophlebitis
- Pacemaker
- Reproductive organs
- Impaired sensation/circulation

Adverse Events



- Precaution: Tissue/bone burn
  - Keep sound head moving
  - Monitor throughout treatment

Module III: Treatment Parameters

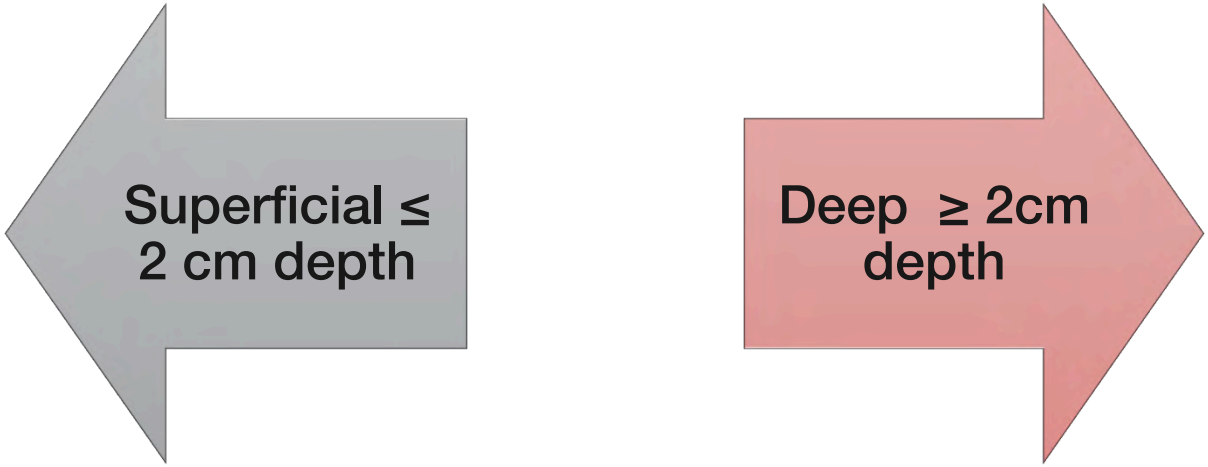
Thermotherapy

Superficial heat

- Moist Heat (conduction)
- Contrast Bath (convection)
- Hydrotherapy (convection)
- Fluidotherapy (convection)
- Paraffin Bath (conduction)

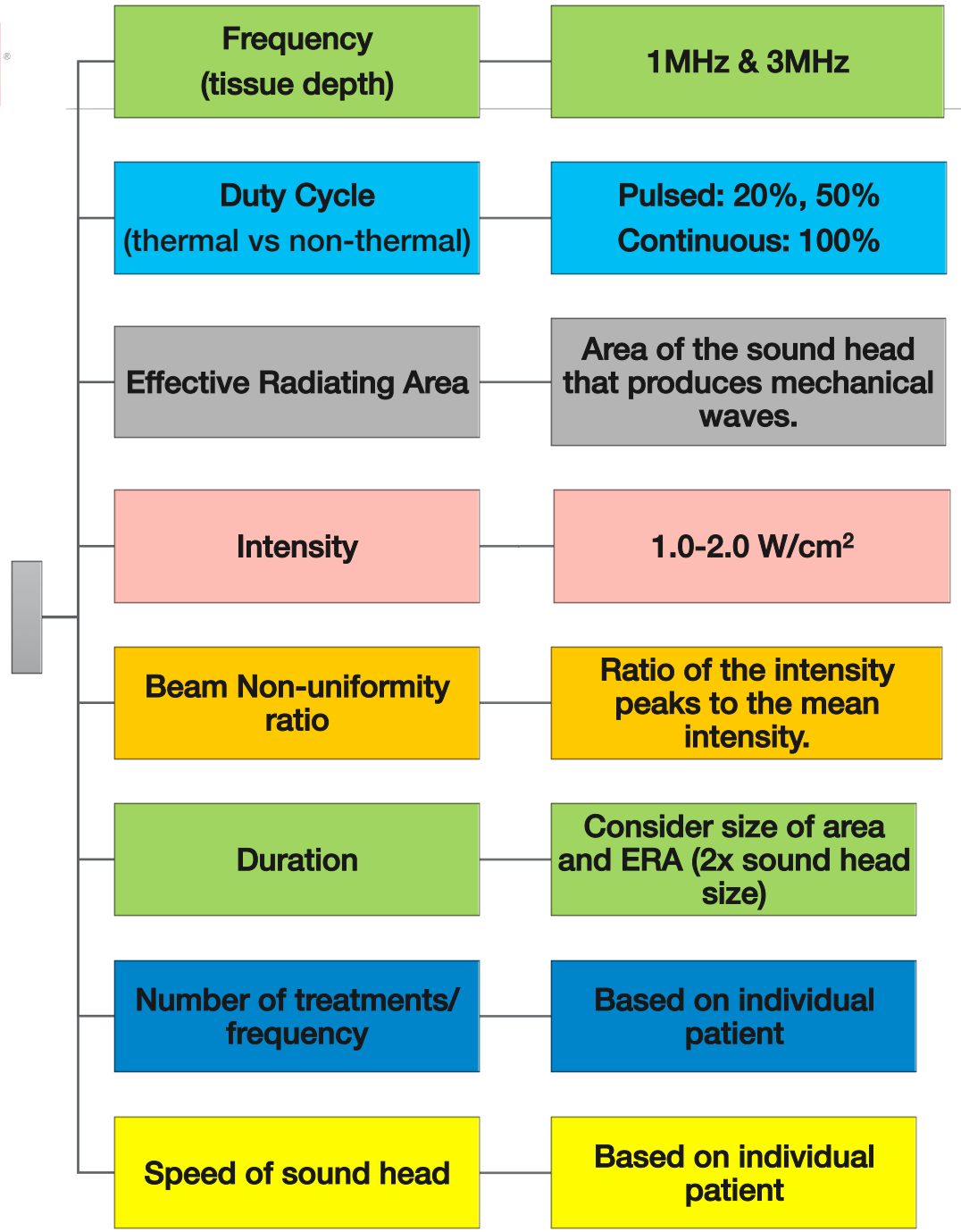
Deep heat

- SW Diathermy (conversion)
- Ultrasound (conversion)

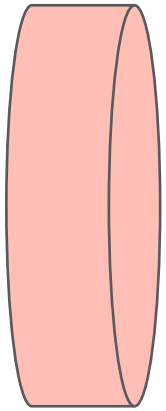


What are the therapeutic ultrasound treatment parameters?

Cameron MH, Sutkus A. *Physical Agents in Rehabilitation - E Book: An Evidence-Based Approach to Practice.* Elsevier Health Sciences; 2017.


Frequency (tissue depth)
1MHz & 3MHz
Duty Cycle (thermal vs non-thermal)
Pulsed: 20%, 50%
Continuous: 100%
Effective Radiating Area
Area of the sound head that produces mechanical waves.
Intensity
1.0-2.0 W/cm2
Beam Non-uniformity ratio
Ratio of the intensity peaks to the mean intensity.
Duration
Consider size of area and ERA (2x sound head size)
Number of treatments/ frequency
Based on individual patient
Speed of sound head
Based on individual patient

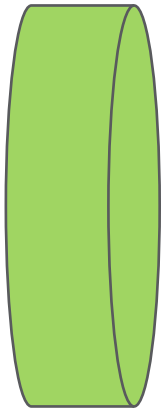
Frequency



3 MHz

Superficial Tissue (<2cm)

Short wavelength = absorbed rapidly by superficial tissues



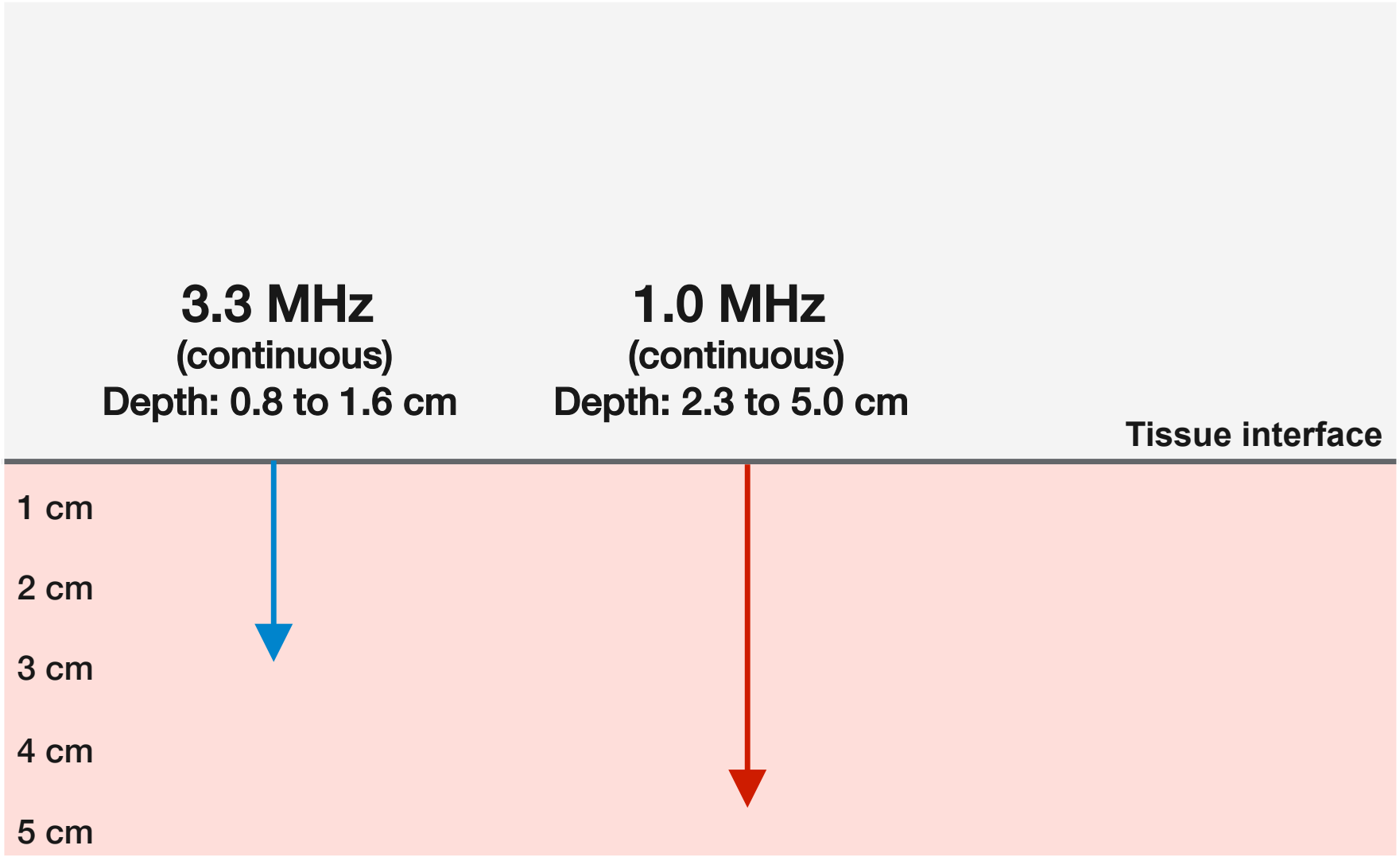
1 MHz

Deep Tissue (2-5cm)

Long wavelength = absorbed by deeper tissues

Frequency

Depth of Ultrasound Wave

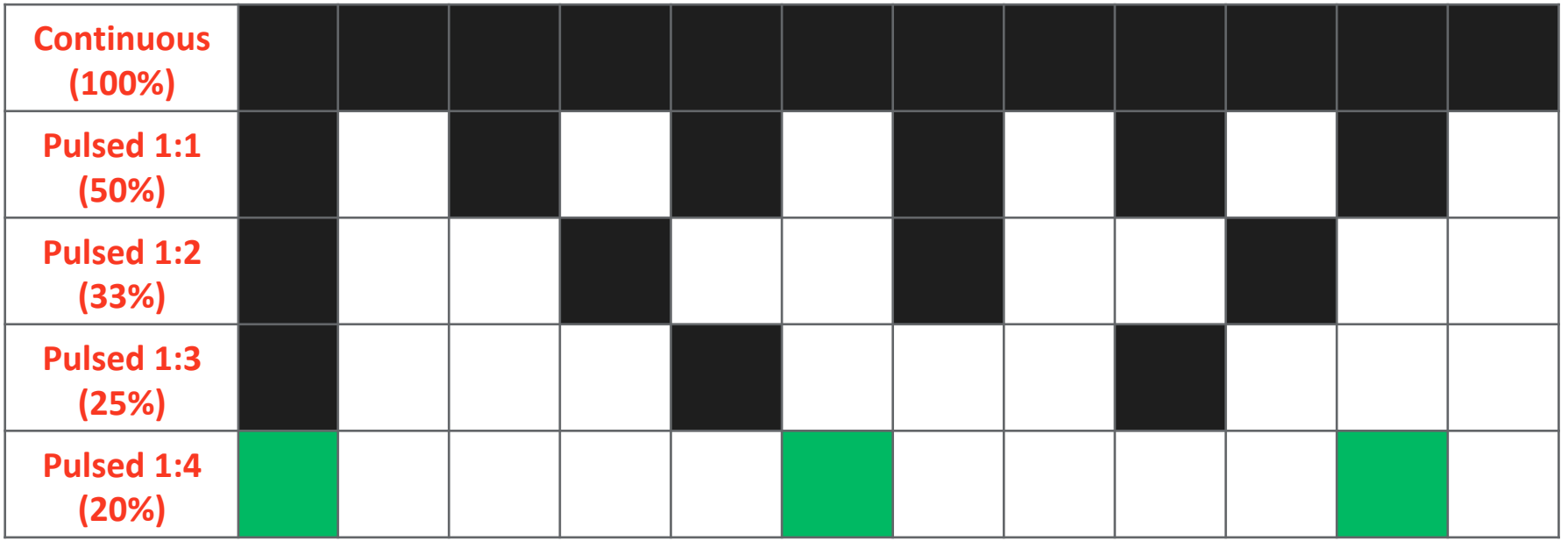


Duty Cycle

Duty cycle = duration of pulse (time on) / pulse period (time on + time off)

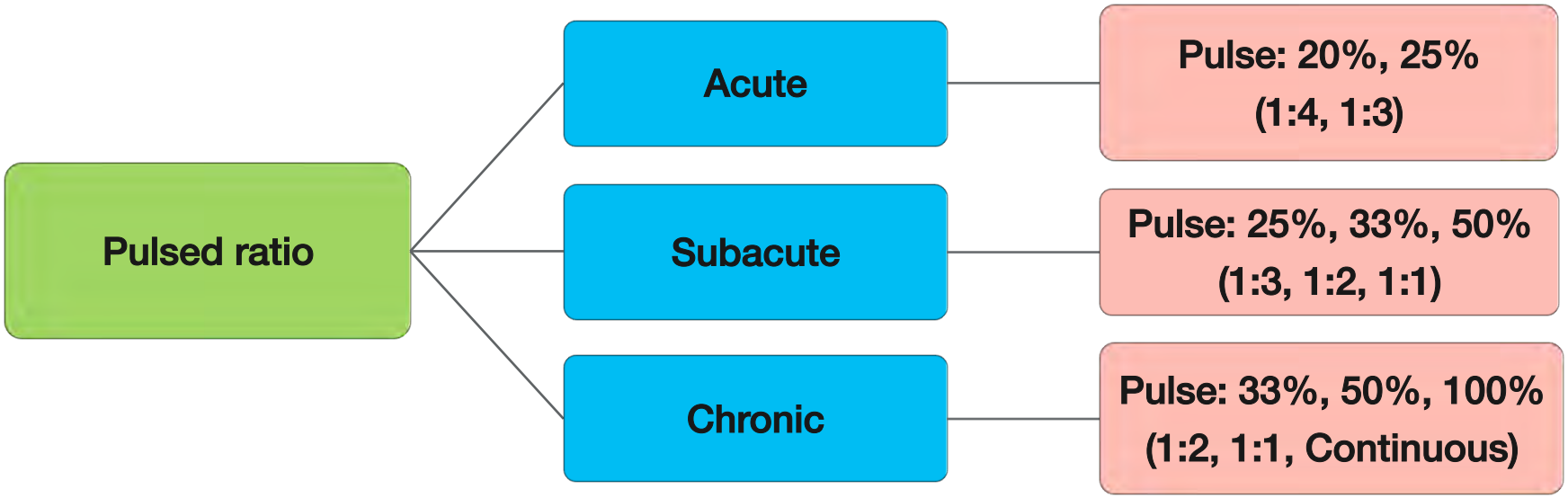
US Mode	Pulse Ratio	Duty Cycle	Effect
Continuous		100%	Thermal
Pulsed	1:1	50%	Non-Thermal
	1:2	33%	Non-Thermal
	1:3	25%	Non-Thermal
	1:4	20%	Non-Thermal

Duty Cycle

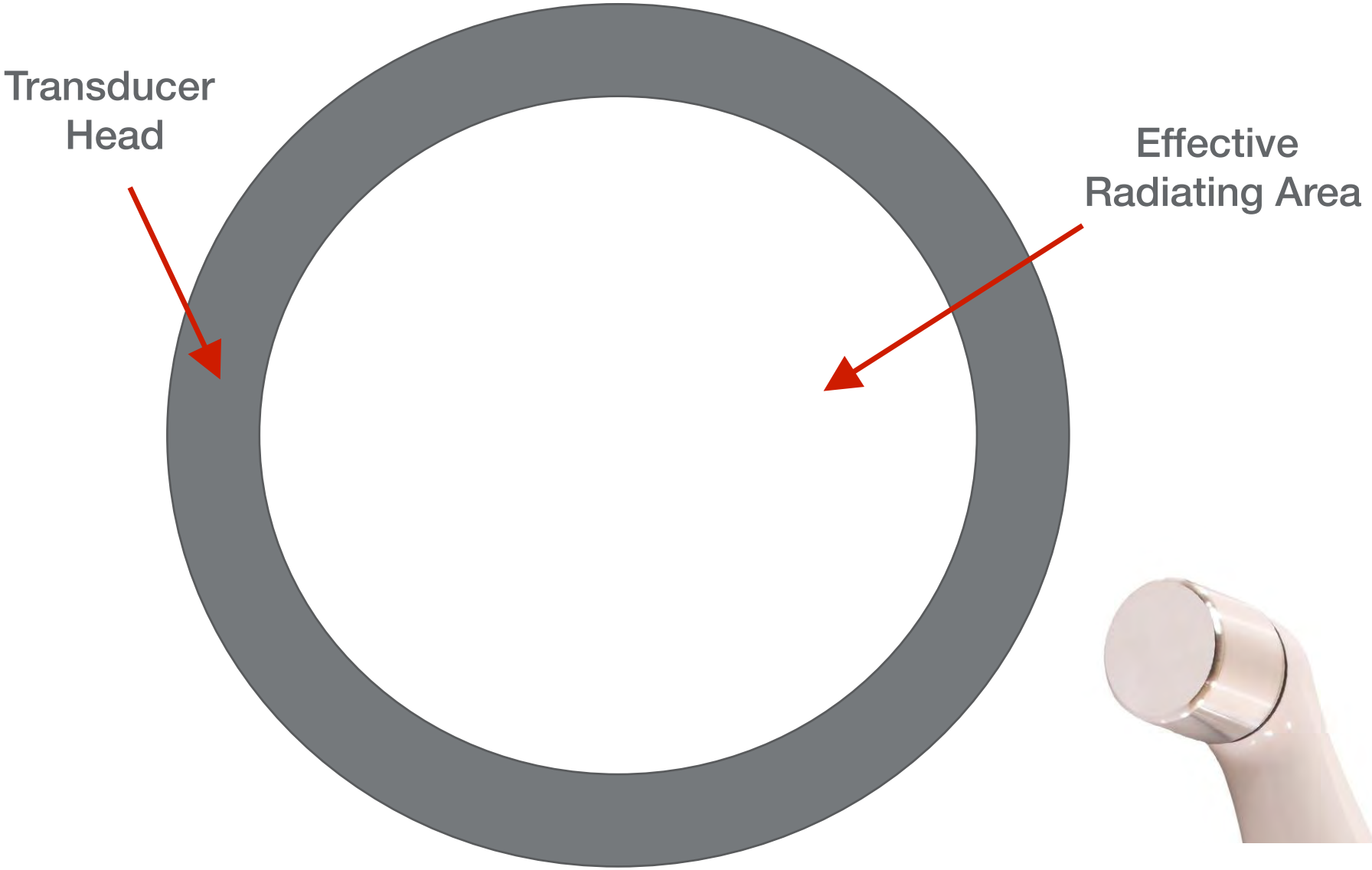


Note: 50% duty cycle provides less time between pulses for the tissues to cool versus a 20% duty cycle.

Duty Cycle


Pulsed ratio
Acute
Subacute
Chronic
Pulse: 20%, 25%
(1:4, 1:3)
Pulse: 25%, 33%, 50%
(1:3, 1:2, 1:1)
Pulse: 33%, 50%, 100%
(1:2, 1:1, Continuous)

Effective Radiating Area



Effective Radiating Area

Treatment area in relationship to the US head size

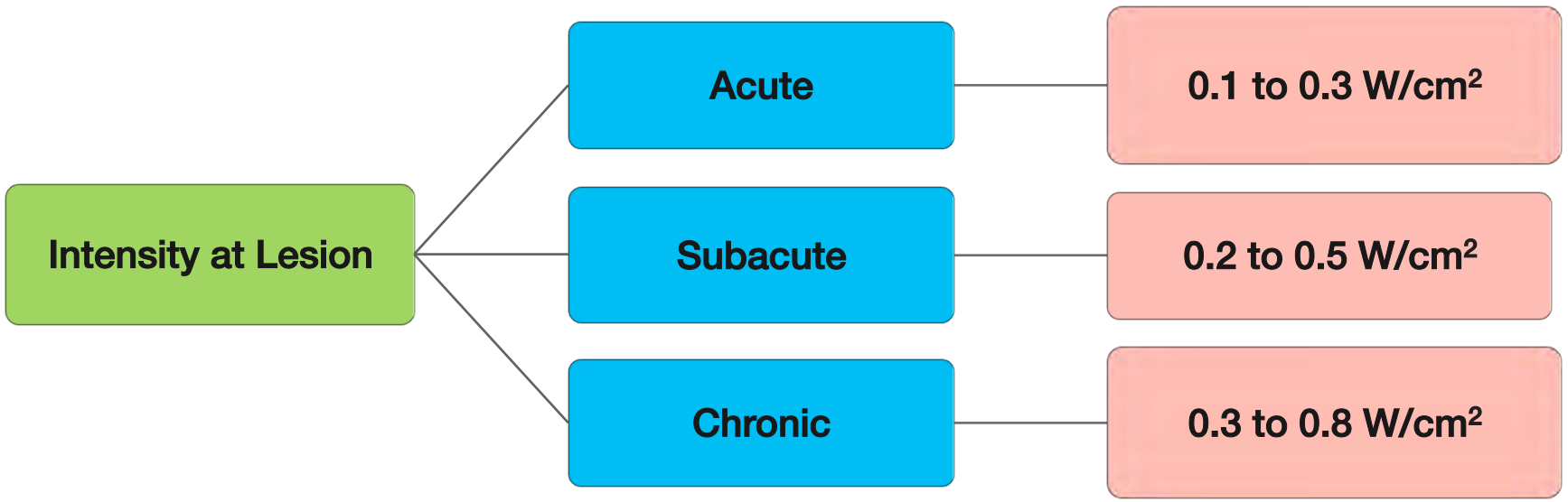
2x size of the transducer head (faceplate)

- **Common transducer sizes**
  - 1 cm^2
  - 2 cm^2
  - 5 cm^2
  - 10 cm^2

e.g. Treatment Area = 10cm^2 x 2 = 20cm^2

Intensity

- **Intensity:** Determines strength of the US beam
- Watts/square centimeter
- W/cm^2



Beam Non-Uniformity Ratio

$$\text{BNR} = \frac{\text{spatial peak intensity}}{\text{spatial average intensity}}$$

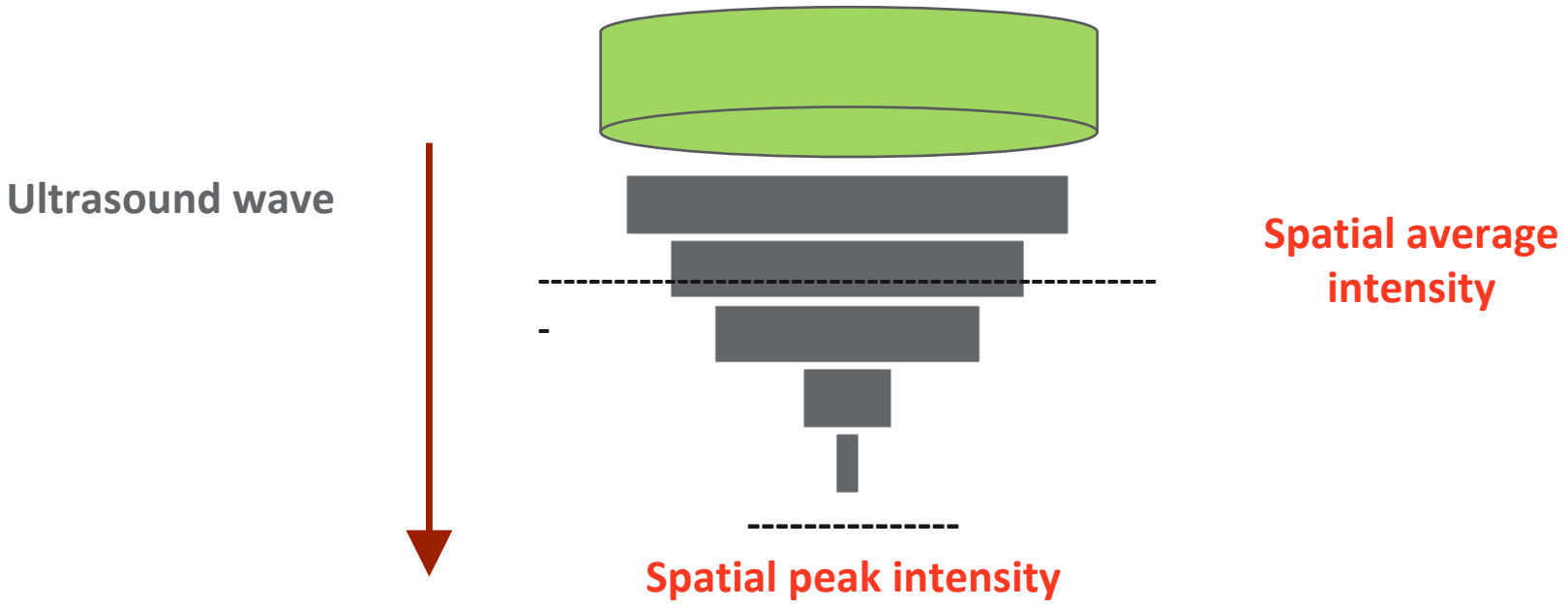
- **BNR-** The maximum point intensity on the transducer to the average intensity across the transducer surface
  - Most common
    - 2:1 and 6:1
    - Low BNR ratio: more even energy distribution = less risk of tissue injury.

Beam Non-Uniformity Ratio

- **Spatial average intensity**

$$\frac{\text{Total Power (watts)}}{\text{Area (cm}^2\text{)}}$$

- **Spatial peak intensity**
  - Greatest level of intensity anywhere within the beam.



Soundhead Motion

- Soundhead motion avoids burns
  - Longitudinal or circular patterns
  - Speed: 4 cm/sec
  - Total area: 2x size of ERA

U.S. Parameter Considerations

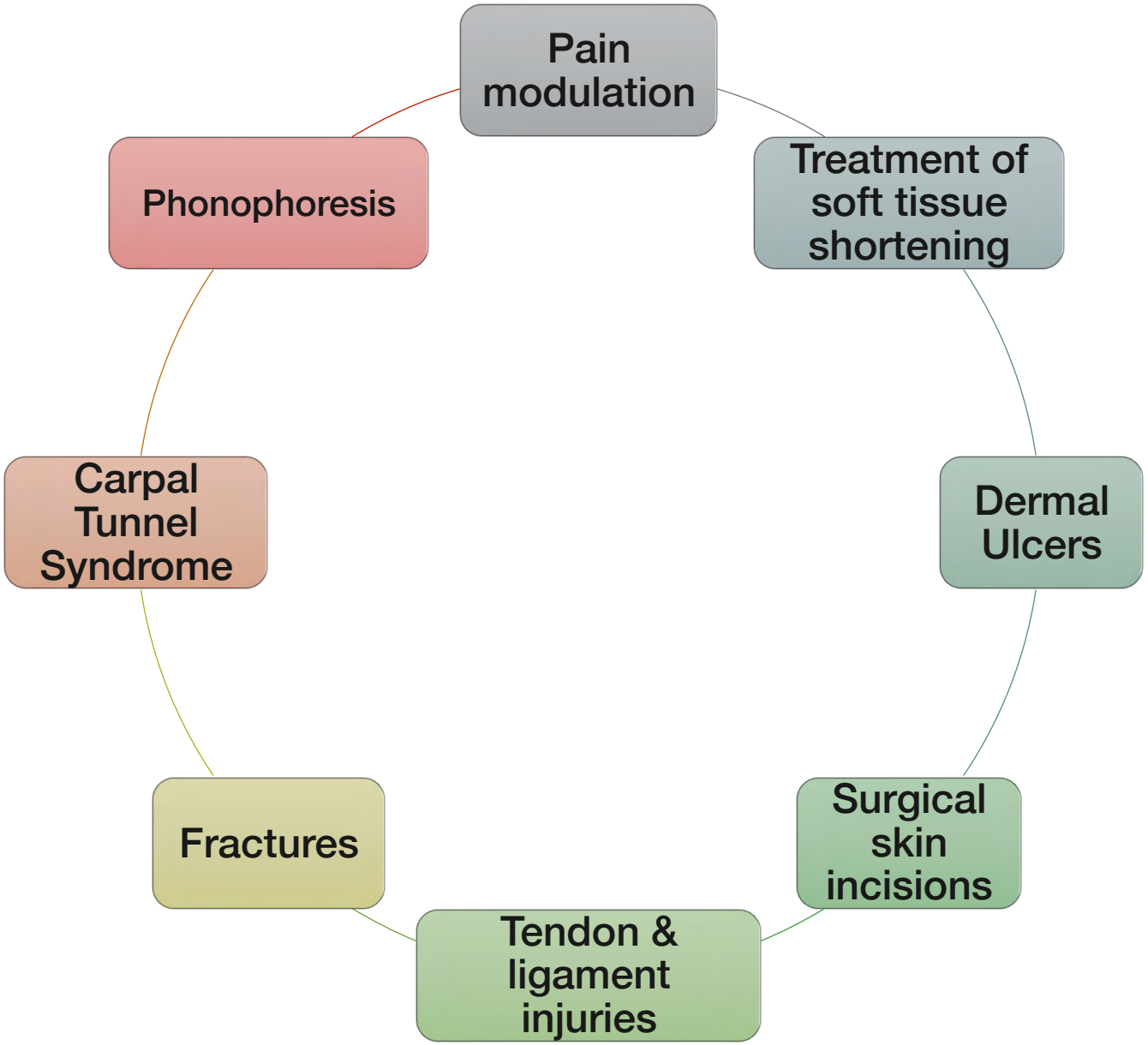
- **Frequency:** Superficial or Deep Tissue?
- **Duty Cycle:** Thermal or Non-Thermal?
- **ERA:** Size of treatment area?
- **Intensity:** 0.5 to 2.0 W/cm^2 ? Patient feedback is important
- **BNR:** What tissues are you trying to affect? Be careful over superficial areas (e.g. ankle/foot)
- **Soundhead Movement:** 4 cm/sec (2x size of ERA)
- **Tx Duration:** Size of treatment area?
- **Tx Frequency:** Phase of tissue healing? Treatment Goal?

Bottom Line

- Occupational Therapist considerations:
  - Treatment parameters need to match the intervention goal and should benefit the patient treatment.
  - The OT must have a working knowledge of U.S. parameters in order to provide safe patient treatment.
  - The OT must consider the safety of using U.S. with each patient.

Module IV: Treatment Application

Clinical Indications



Pain Control

- U.S.
  - Intensity: 0.5 to 3.0 W/cm2
  - Duty Cycle: 100% continuous (preferred)
  - Duration: 3 to 10 min
  - Frequency: 3 MHz or 1 MHz
  - Speed: 4 cm/sec
  - Total area: 2x size of ERA

Soft-Tissue Healing

- U.S.
  - Intensity: 0.5 to 1.0 W/cm2
  - Duty Cycle: 20% pulsed (preferred)
  - Duration: 3 to 10 min
  - Frequency: 3 MHz (preferred)
  - Speed: 4 cm/sec
  - Total area: 2x size of ERA

Soft Tissue Shortening

- U.S.
  - Intensity:
    - 3 MHz: 0.5 to 1.0 W/cm2
    - 1 MHz: 1.5 to 2.5 W/cm2
  - Duty Cycle: 100% continuous (preferred)
  - Duration: 5 to 10 min
  - Frequency: 3 MHz or 1 MHz
  - Speed: 4 cm/sec
  - Total area: 2x size of ERA

Ligament and Tendon Injury

- U.S.
  - Intensity: 0.5 to 1.0 W/cm2
  - Duty Cycle: 20% to 50% pulsed (recommended)
  - Duration: 3 to 10 min
  - Frequency: 3 MHz or 1MHz
  - Speed: 4 cm/sec
  - Total area: 2x size of ERA

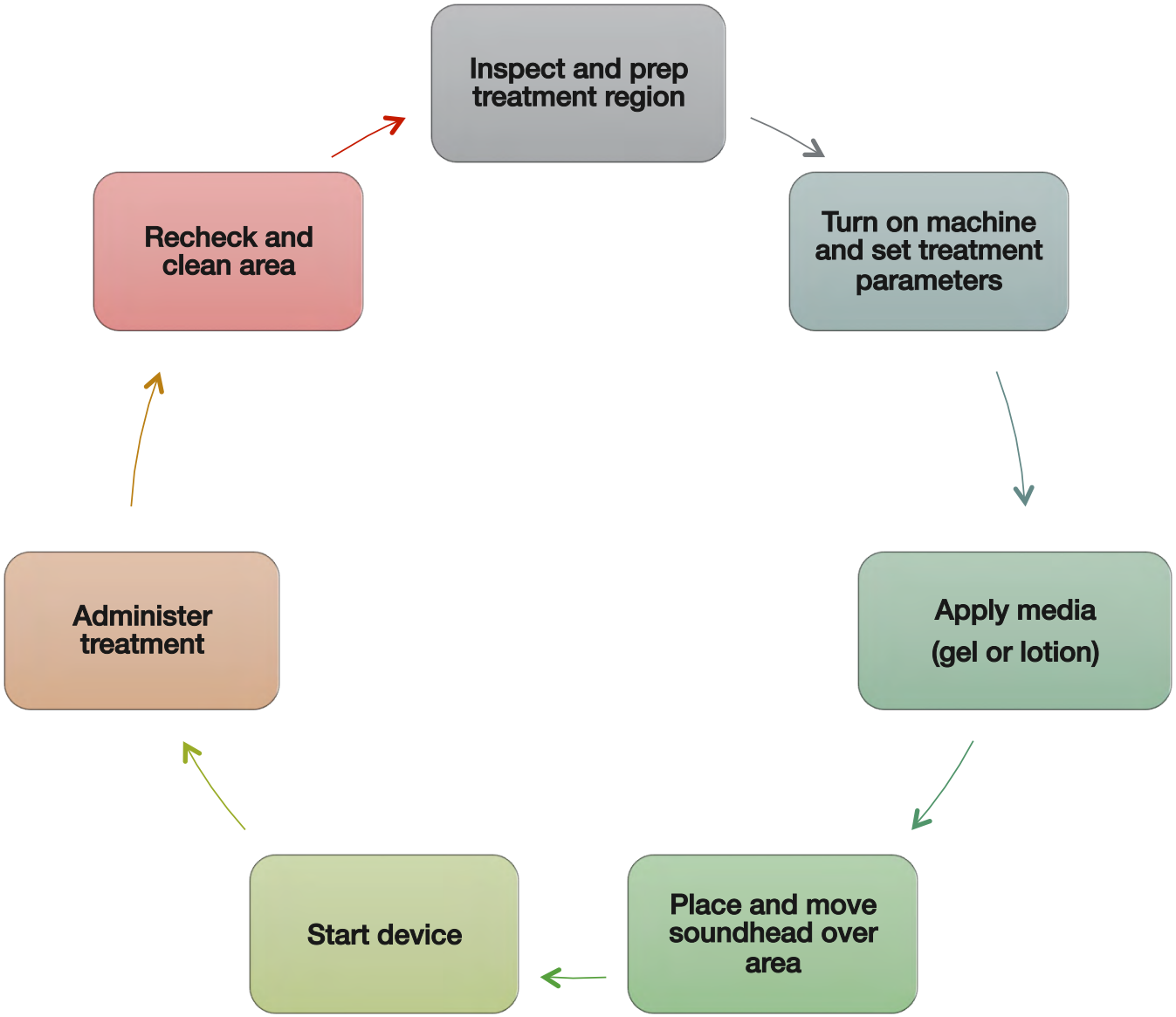
Bone Fractures

- U.S.
  - Intensity: 0.15 W/cm2
  - Duty Cycle: 20% pulsed
  - Duration: 15 to 20 min
  - Frequency: 1.5 MHz
  - Speed: NA
  - Total area: NA
  - *Device: Specific device with application pads used over FX

Carpal Tunnel Syndrome

- U.S.
  - Intensity: 1.0 W/cm2
  - Duty Cycle: 20% pulsed
  - Duration: 5 to 15 min
  - Frequency: 1 MHz
  - Speed: 4 cm/sec
  - Total area: 2x size of ERA

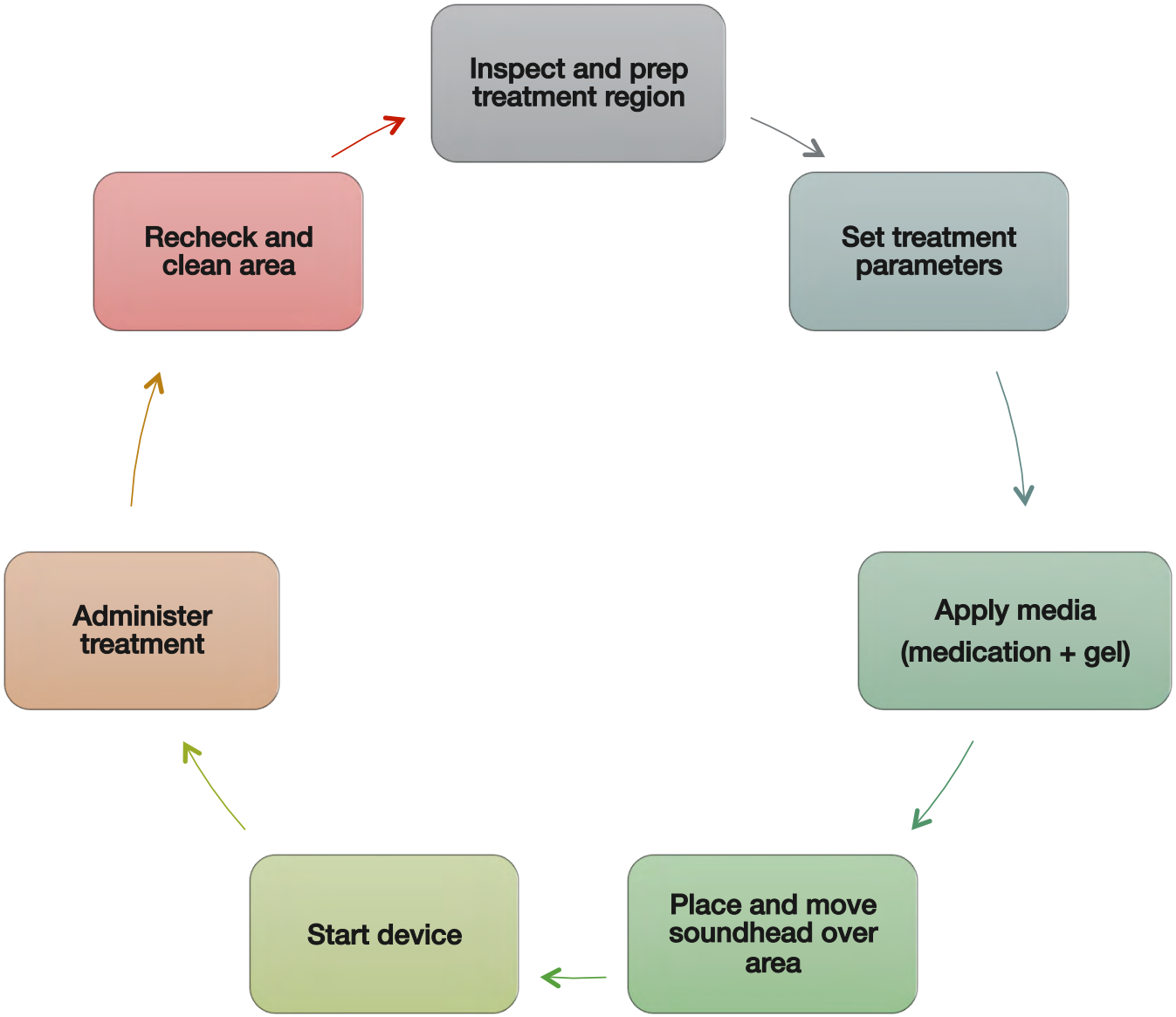
Ultrasound


Inspect and prep treatment region
Turn on machine and set treatment parameters
Apply media (gel or lotion)
Place and move soundhead over area
Start device
Administer treatment
Recheck and clean area

Phonophoresis

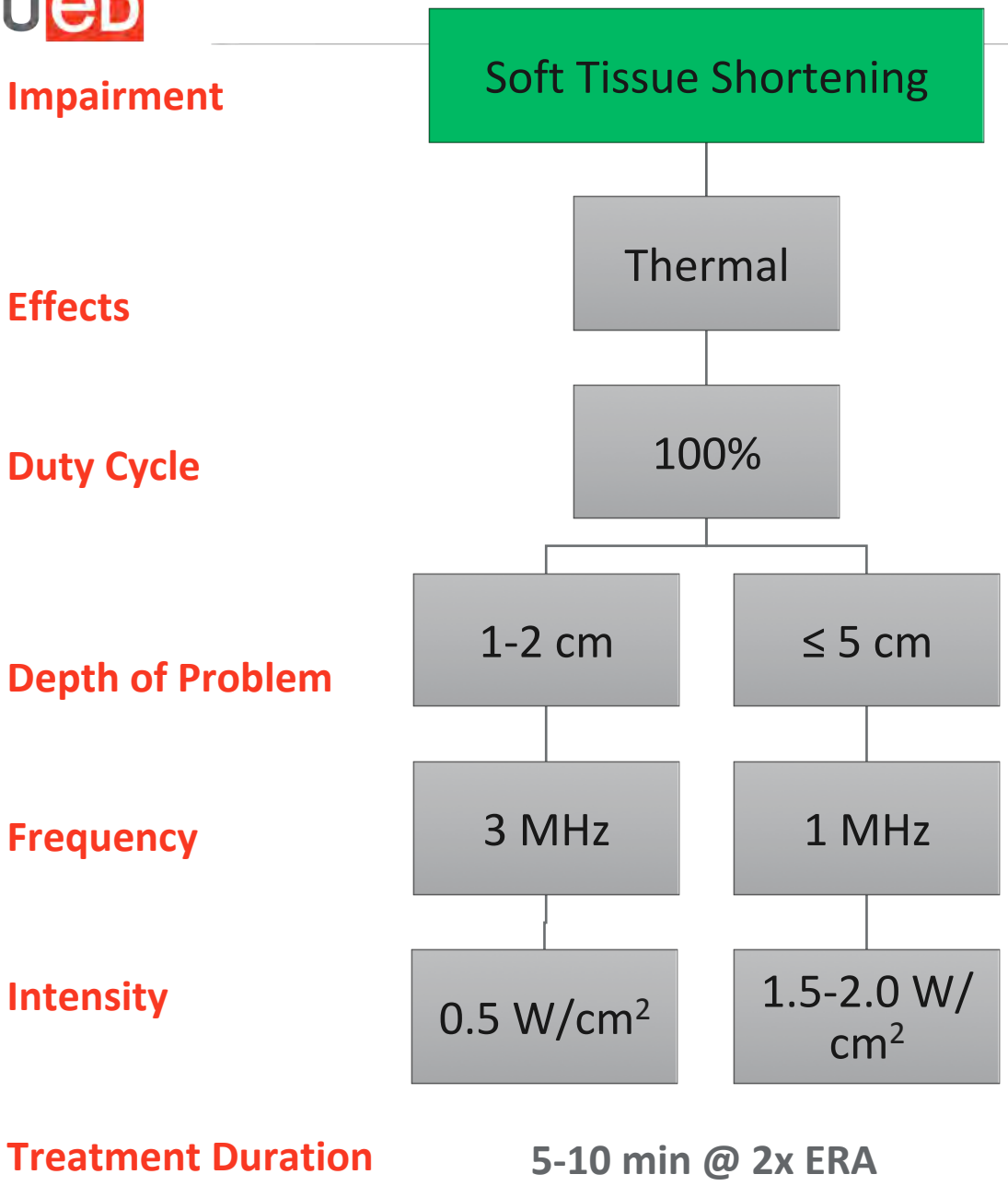
- Phono
  - Intensity: 0.5 to 1.0 W/cm2
  - Duty Cycle: 20% pulsed (preferred)
  - Duration: 5 to 10 min
  - Frequency: 3 MHz (preferred) or 1 MHz
  - Speed: 4 cm/sec
  - Total area: 2x size of ERA

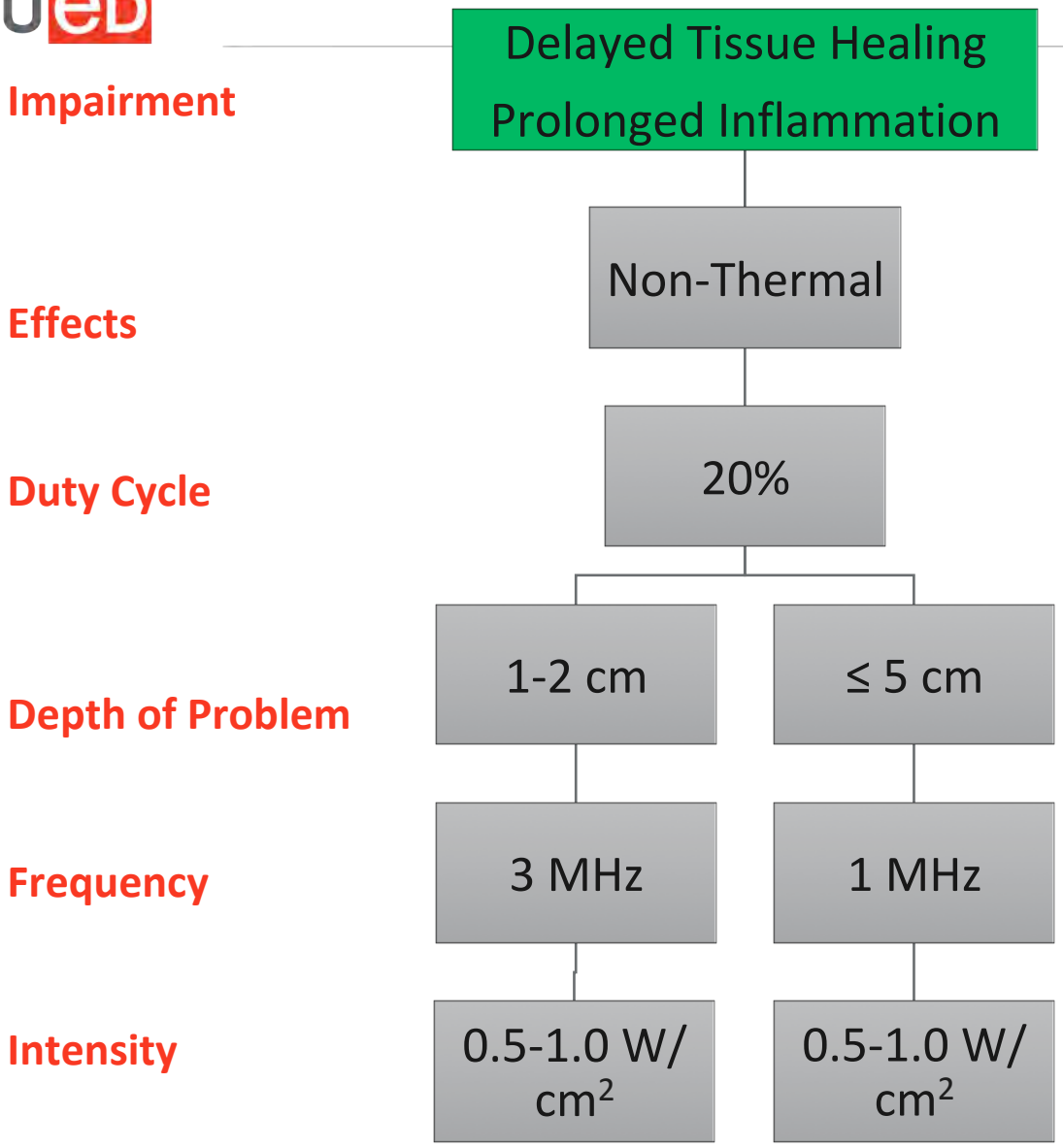
Phonophoresis



Treatment Examples

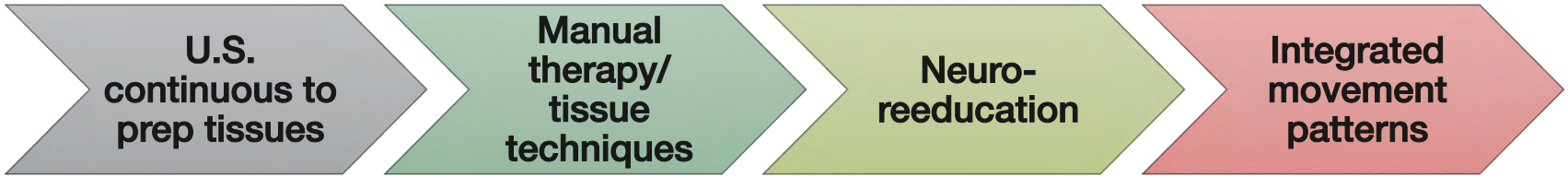
Cameron MH, Sutkus A. *Physical Agents in Rehabilitation - E Book: An Evidence-Based Approach to Practice.* Elsevier Health Sciences; 2017.


Impairment
Soft Tissue Shortening
Effects
Thermal
Duty Cycle
100%
Depth of Problem
1-2 cm
≤ 5 cm
Frequency
3 MHz
1 MHz
Intensity
0.5 W/cm2
1.5-2.0 W/ cm2
Treatment Duration
5-10 min @ 2x ERA

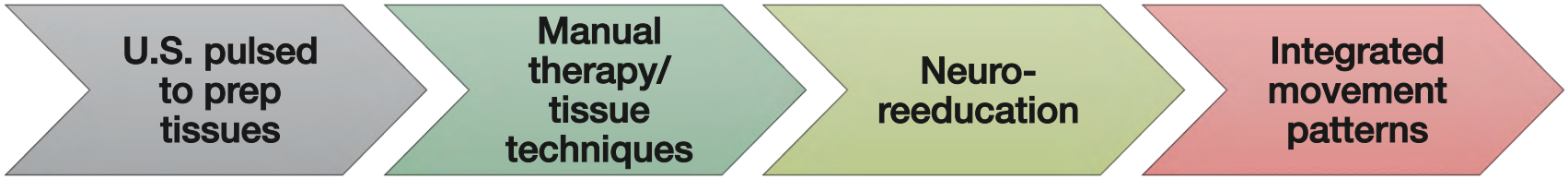

Impairment
Delayed Tissue Healing
Prolonged Inflammation
Effects
Non-Thermal
Duty Cycle
20%
Depth of Problem
1-2 cm
≤ 5 cm
Frequency
3 MHz
1 MHz
Intensity
0.5-1.0 W/ cm²
0.5-1.0 W/ cm²
Treatment Duration
5-10 min @ 2x ERA

Suggested Integrative Treatment

- **Goal: U.S. Thermal effect**



- **Goal: U.S. Non-thermal effect**



- **Goal: Phonophoresis**

Bottom Line

- Occupational Therapist considerations
  - U.S. and Phono have some good utility for different MSK conditions.
  - The current research provides some clinical guidelines.
  - Treatment parameters should be chosen and adjusted based upon the research, treatment goals, and patient response to treatment.
  - The OT must consider the safety of using these treatment methods with each patient.

Module V: Ultrasound Research

Ultrasound Research

2010-2020

Evidence Summary

- The body of therapeutic ultrasound evidence is large with over 40 years of published studies.
- There is moderate evidence supporting the treatment of different MSK conditions. However, there are some studies that reported inconclusive results.
- This section will summarize the most relevant evidence from the past twenty years based upon common clinical questions.

Therapeutic Ultrasound

- **Q: Does ultrasound decrease pain, increase joint ROM and function after musculoskeletal injury or pathology?**
  - (+): Ultrasound had positive results for all outcomes
    - 2019- Wu et al. *Clin Rehabil (Knee OA)*
    - 2018- Ozgonenel et al. *J Med Ultrasound (Knee OA)*
    - 2016- Zhang et al. *Clin Rehabil (Knee OA)*
    - 2017- Yegin et al. *Ultrasound Med Biol* (Knee OA)
    - 2010- Rutjes et al. *Cochrane Database Review (Knee OA)*
  - (-): Ultrasound had weak to no results for all outcomes
    - 2020- Ebadi et al. *Cochrane Database Review (LBP)*
    - 2020- Karakas et al. *Clin Rehabil (Knee OA)*
    - 2020- Papadopoulos and Mani. *Int J Low Extrem Wounds (LE Pain)*
    - 2010- Shanks et al. *Foot (LE MSK)*

Therapeutic Ultrasound

- **Q: Does ultrasound provide greater benefits than Low-Level Laser Therapy?**
  - (±) U.S. provided similar benefits as LLLT
    - 2020- Asheghan et al. *Laser Ther (CTS)*
    - 2019- Rayegani et al. *J Lasers Med Sci (CTS)*
    - 2019- Rubira et al. *Adv Rheumatol (LBP)*
    - 2015- Boyraz. *BioMed Res Int (LDD)*
    - 2014- Yavuz et al. *J Back Musculoskelet Rehabil (SIS)*
  - (+) U.S. provided better results than LLLT.
    - 2018- Li et al. *Medicine (Plantar Fasciitis)*
  - (-) LLLT provided better results than U.S.
    - 2019- Budakoti et al. *Lasers in Dent Sci (TMD)*

Therapeutic Ultrasound

- **Q: Does Ultrasound provide greater benefits than Extracorporeal Shockwave Therapy?**
  - (±) Both modalities provided similar benefits
    - 2019- Dedes eta al. *Folia Med (RC Tendinopathy)*
    - 2018- Li et al. *Medicine (Plantar Fasciitis)*
  - (-) EST provided greater benefits than U.S.
    - 2019- Dedes eta al. *Acta Inform Med (Plantar Fasciitis)*
    - 2001- Dedes eta al. *J Med Ultrason (Lateral Epicondylitis)*

Phonophoresis

- **Q: Does Phonophoresis decrease pain, increase joint ROM and function after musculoskeletal injury or pathology?**
  - (+): Phono had positive results for all outcomes
    - 2018- Benlidayi et al. *Rheumatology Int (Knee OA)*
    - 2019- Ahmed et al. *Indian J Orthop (Knee OA)*
    - 2014- Durmas et al. *Rheumatol Int (Cervical pain)*
    - 2014- Durmas et al. *Rheumatol Int (LBP)*
- **Q: Does Phonophoresis provide greater benefits than Shortwave Diathermy or Therapeutic Ultrasound?**
  - (±) All modalities provided similar benefits
    - 2013- Boyaci et al. *Rheumatol Int (Knee OA)*

Phonophoresis

- **Q: Does Phonophoresis provide greater benefits than Therapeutic Ultrasound?**
  - (+) Phono provided greater benefits than U.S.
    - 2019- Altan et al. *Ultrasonics (LBP)*
    - 2019- Ramakrishnan and Awwath. *Indian J Dent Res (TMD)*
    - 2015- Boyraz. *BioMed Res Int (LDD)*
    - 2014- Yavuz et al. *J Back Musculoskelet Rehabil (SIS)*
    - 2014- Ustun et al. *Rheumatol Int (MFPS)*
    - 2013- Luksurapan and Boonhong*. Ach Phys Med Rehabil (Knee OA)*
  - (±) Phono provided similar benefits as U.S.
    - 2020- Boonhong and Thienkul. *PMR (CTS)*
    - 2019- Wu et al. Clin Rehabil (Knee OA)
    - 2019- Saime et al. *Rheumatol Int (MFPS)*
    - 2014- Durmas et al. *Rheumatol Int (LBP)*

Bottom Line

- Occupational Therapist considerations
  - The evidence supports the use of U.S. methods for the indications discussed in this presentation.
  - There seems to be a consensus among researchers and clinicians regarding the efficacy of this intervention.
  - Phono: most studies used some type of anti-inflammatory medication:
    - Dexamethasone, Diclofenac, Ibuprofen, Piroxicam, etc.

Module VI: Device Hygiene

Soundhead Hygiene

- **Soundhead disinfecting:**
  - Use intermediate-level disinfectant to clean handle and soundhead surface. *Clean gel/lotion container
  - If the soundhead contacts blood, bodily fluids, mucous membranes, or non-intact skin, then a high-level disinfectant or sterilization should be done.

Center for Disease Control Levels of Disinfection	
High-level disinfection	These disinfectants kill all organisms, except high levels of bacterial spores, and is effected with a chemical germicide cleared for marketing as a sterilant by FDA. Typically, they are not used for generalized disinfecting.
Intermediate-level disinfection	These disinfectants kill mycobacterium, most viruses, and bacteria with a chemical germicide registered as a "tuberculocide" by EPA.
Low-level disinfection	These disinfectants kill some viruses and bacteria such as HIV and HBV with a chemical germicide registered as a hospital disinfectant by the EPA.
EPA: Environmental Protective Agency	

U.S. Safe Treatment Sequence Recommendations	
Step 1	Wash hands with soap and water or rubbing hands together using an alcohol-based hand sanitizer (e.g., gel or wipe) for a minimum of 20 seconds. Wear personal protective equipment (PPE) during treatment, as necessary.
Step 2	Before treatment, the body region is inspected and cleared for treatment. Then the patient's skin (at the treatment site) is cleaned with a low-level sanitizing wipe (e.g. Purell®) that is safe for the skin, or 60-70% isopropyl alcohol to further reduce the risk of infection.
Step 3	The U.S. treatment is administered using the media (gel) and PPE procedures, as needed.
Step 4	During the prescribed treatment, the professional monitors for changes in the patient's status (e.g., pain, sensitivity to treatment, etc.)
Step 5	Upon completion of treatment, the body region is re-inspected and cleaned again using a sanitizing wipe or isopropyl alcohol.
Step 6	The professional concludes with post treatment hand hygiene, disposing of any PPE, and cleaning of the equipment using an intermediate level disinfectant.

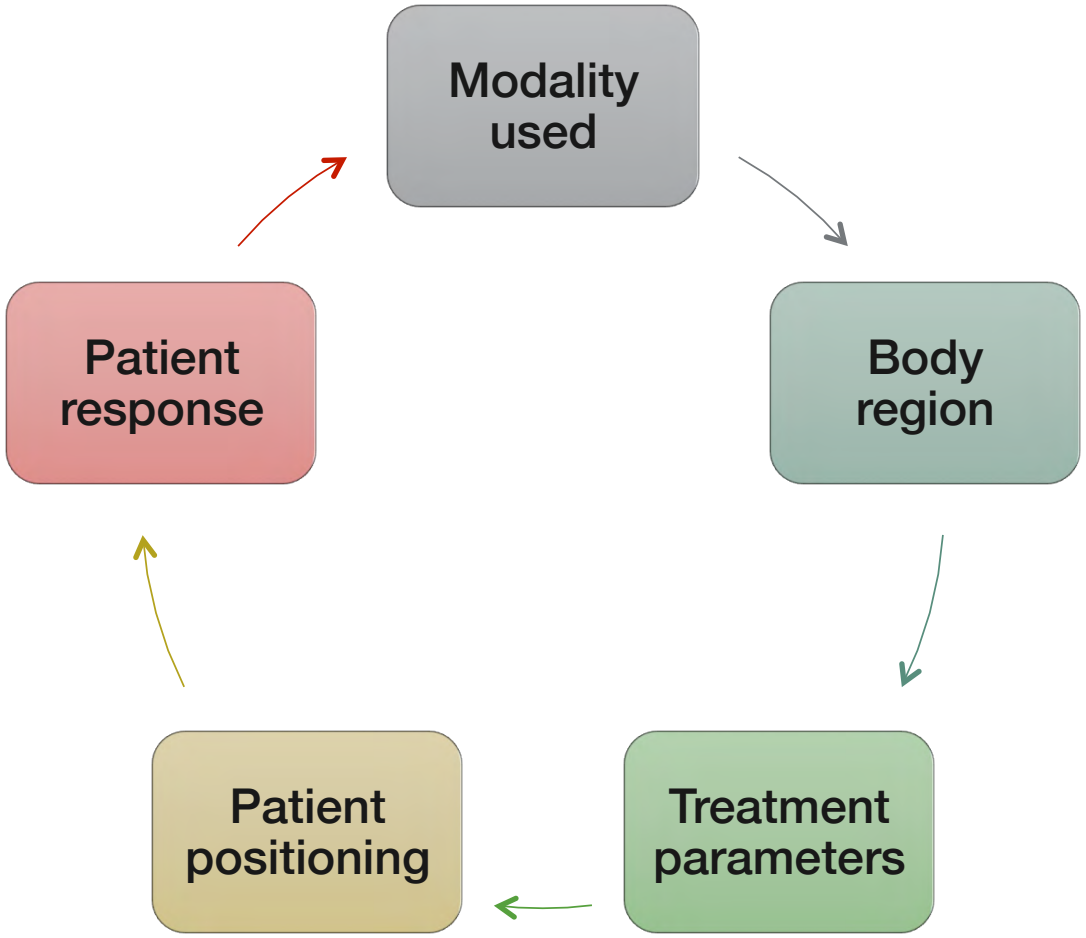
Bottom Line

- Occupational Therapist considerations
  - Use an intermediate-level disinfectant to clean device.
    - Clorox® and Lysol® brand wipes, 70% isopropyl alcohol
  - Follow the recommended “wet time” (e.g. 4 min/ disinfect)
  - Wear proper PPE per the product recommendations
    - At minimum, gloves and maybe a mask (e.g. harmful odor)

Module VII: Documentation

Charting Recommendations

Occupational Therapists should chart the following information for each treatment



CPT Coding for Modalities

CPT Code	Description
97010	Hot/Cold Packs
97012	Mechanical Traction
97014	Electrical Stimulation (unattended)
97024	Diathermy
97032	Electrical Stimulation (manual)
97033	Iontophoresis
97035	Ultrasound/Phonophoresis
G0283	Electrical Stimulation, Medicare (unattended)

https://www.physicaltherapy.com/articles/medicare-part-b-coding-and-3841

Common Charting Examples

- **Goal: U.S. thermal effect**
  - **Rationale**: Pain control, soft-tissue shortening
  - **Daily Note:** U.S. 1.0 W/cm^2 x 8 min continuous to left knee quadriceps tendon, 5 cm head with U.S. gel, patient supine. Patient tolerated treatment with no incident.
- **Goal: U.S. non-thermal effect**
  - **Rationale:** Soft-tissue healing, ligament/tendon injury, CTS, bone FX
  - **Daily Note:** U.S. 0.5 W/cm^2 x 8 min 20% pulsed to right distal Achilles tendon, 10 cm head with U.S. gel, patient prone. Patient tolerated treatment with no incident.
- **Goal: Phonophoresis**
  - **Rationale:** Pain relief and anti-inflammatory effects
  - **Daily Note:** Phono 0.5 W/cm^2 x 8 min 20% pulsed to right distal Achilles tendon, 10 cm head with 1cc Dexamethasone and gel, patient prone. Patient tolerated treatment with no incident.

Bottom Line

- Occupational Therapist Considerations
  - The clinician must document all details of a modality when used in patient care.
  - Patient injuries from misuse or poor supervision are common.
  - Modalities should be used when necessary to facilitate the patient's progress in rehabilitation.

Final Thoughts

Ultrasound

- Should be an adjunct to a comprehensive rehabilitation program.
- Choosing the best U.S. parameters for a specific phase of rehabilitation or MSK condition may enhance a patient's recovery.
- Proper documentation and patient supervision during modality treatment are key for safe patient care.

Thanks!!!

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