

# **ULTRASOUND & ELECTRICAL STIMULATION FOR WOUND HEALING**

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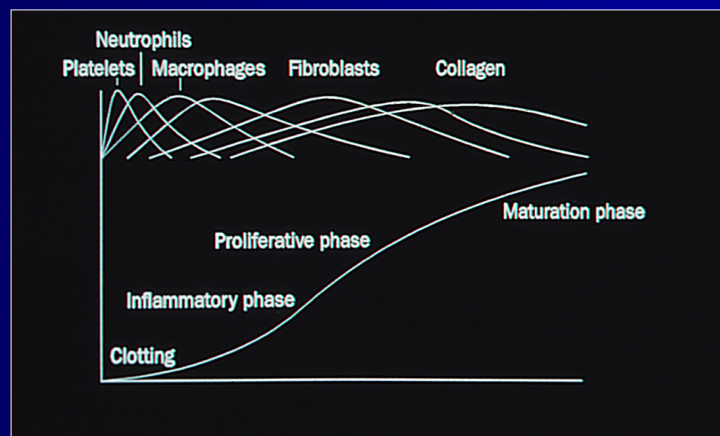
## **ACKNOWLEDGMENT**

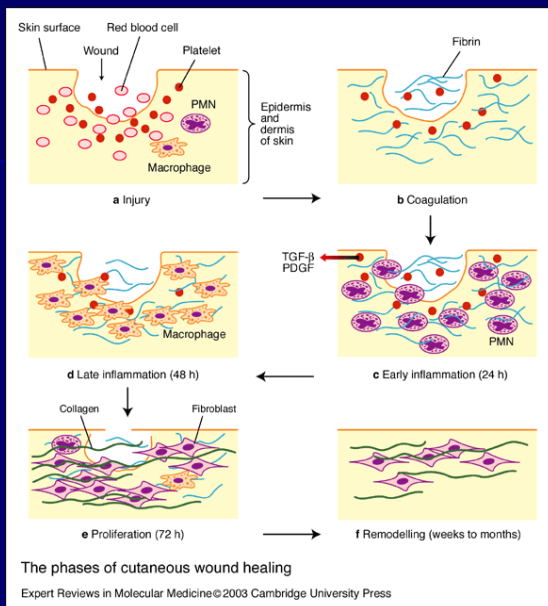
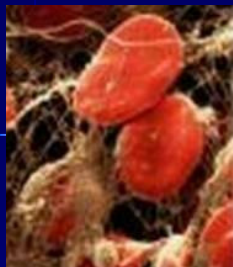
- **Key content in the following presentation was derived, with kind permission, from Dr. Pamela Houghton, Associate Professor, University of Western Ontario**

## MANAGEMENT OF WOUNDS

- Thorough **assessment**
  - **Type**: diabetic, pressure, arterial, venous
  - **Staging**: eg. Inflammatory, proliferative
  - Other: eg. tunneling
  - **Patient factors**: meds, diabetes, nutrition
- Multifocal & **interprofessional** practice
  - Positioning, aids, footwear, reducing friction, dressings, nutrition
- Highly recommended: S1, S2, Nursing courses through VCH; CAWC
- \*Inventory of useful resources for PTs

## Phases of wound healing





## EPAs FOR WOUND HEALING

- Therapeutic Ultrasound
- Electrical Stimulation
- Ultraviolet Light
- LASER

## INFORMED DECISIONS FOR EPAs

Clinical Evidence	Biophy/Physiol Explanation	Recommendation
Some	None	Provisional acceptance
None	Sound	Provisional acceptance
Inconclusive	None	Provisional disapproval
Claims	Contrary to claims	Not acceptable

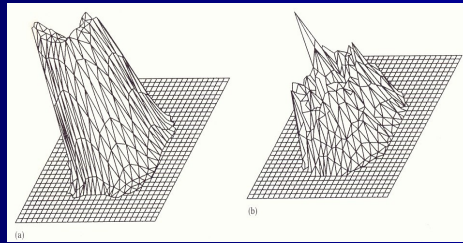
Adapted from Robertson et al, 2006

## THERAPEUTIC ULTRASOUND



## US - THE BASICS

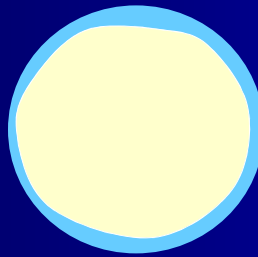
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BNR - BEAM NONUNIFORMITY RATIO

## US - THE BASICS

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EFFECTIVE RADIATING AREA  
> 5% Of Maximum Power Output

## THERAPEUTIC ULTRASOUND

- Keep head moving 3-4 cm/sec
- Limit area to 2 X ERA
- Keep head perpendicular
- \*apply with moderate pressure

## THERAPEUTIC ULTRASOUND

- **US and inflammatory cells**
  - **Phagocytosis** Crowell et al, 1997
  - **Degranulation** Young & Dyson, 1990 Dyson & Luke, 1986
  - **“US is pro-inflammatory”**
    - Gives healing a kick when it is stuck!

## THERAPEUTIC ULTRASOUND

### ■ US and **Fibroblasts**

- **Collagen Synthesis** Harvey et al, 1974
- **Calcium Influx** Al-Karmi et al, 1994
- **Membrane Permeability** Dinno et al, 1988
- **Increased Fibroblast production** DeDeyne & Kirsch-Volders, 1995

## THERAPEUTIC ULTRASOUND

### ■ US and **circulation**

Byl & Hopf	TcPO <sub>2</sub>
Abramson et al, 1960	Blood flow
Maxwell, 1992	O <sub>2</sub> free radical
DelMaestro et al, 1982	Vasc perm & edema, endothelial contract'n
Young & Dyson, 1990	Angiogenesis
*X Hogan et al, 1982	Vasocon.
*X Rubin et al, 1990	Transient vasocon.

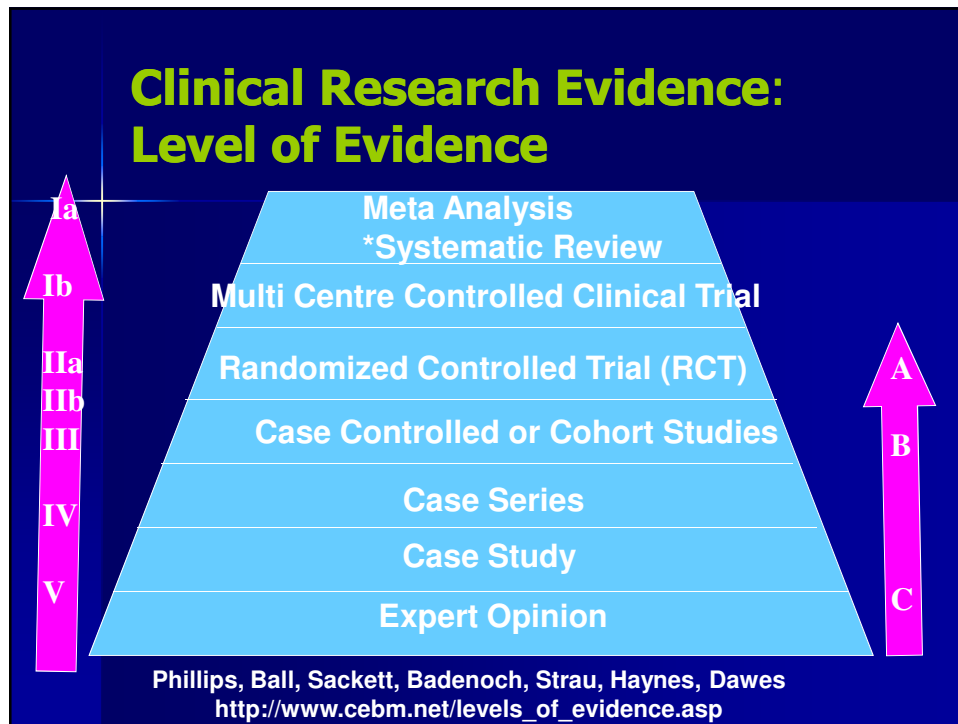
## THERAPEUTIC ULTRASOUND

- US should be used **early** in healing:
  - **0-9 days** Enwemeka, 1989
  - **Optimal scar maturation if US within 7 days post-op** Gan et al, 1995
  - **Optimal collagen synthesis & strength if US used during inflammatory cycle** Jackson et al, 1994

## THERAPEUTIC ULTRASOUND

- **Summary**
  - **Tissue Repair**
    - Enhance epithelial, fibroblasts, endothelial cells to stimulate new tissue growth
  - **Circulation**
    - Improve blood supply to enhance oxygen delivery
  - **\*\*See chart**





## THERAPEUTIC ULTRASOUND

**Venous** ulcers - the available evidence **suggests** that US may increase healing. (Al-Kurdi et al, 2008 \*Cochrane).

**Pressure** ulcers - no evidence of benefit but possibility of beneficial or harmful effects **can not be ruled out** (Baba-Akbari Sari et al, 2008 \*Cochrane)

\*US has **Level B** Strength of Evidence for wound healing (Houghton & Campbell, 2001)

## THERAPEUTIC ULTRASOUND

- **Indications:** Pressure, diabetic, venous, non-infected, abundant necrotic tissue, 'stuck'
- **Contraindications:**
  - Malignancy
  - Canadian Guidelines CPA 2010
- **Application preparation:**
  - Informed consent
  - Sensation test: Hot & cold

## THERAPEUTIC ULTRASOUND

- **Application for wound healing**
  - Surrounding intact skin \*periulcer
  - 0.2 W/cm<sub>2</sub> SATA (dial in 1.0 W/cm<sub>2</sub> SATP for 0.2 W/cm<sub>2</sub> at 20% pulsed)
  - 3 MHz
  - Pulsed 20%
  - 5 minutes/5 cm<sub>2</sub>
- Spatial average temporal average - The temporal average intensity averaged over the beam cross-sectional area

## ELECTRICAL STIMULATION

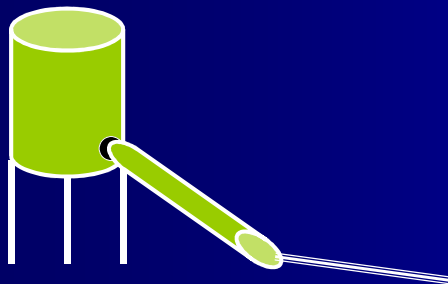
### HIGH VOLTAGE PULSED CURRENT



## ELECTRICAL STIMULATION

### BASIC ELECTRICAL PRINCIPLES

Voltage, Current, Resistance



## ELECTRICAL STIMULATION

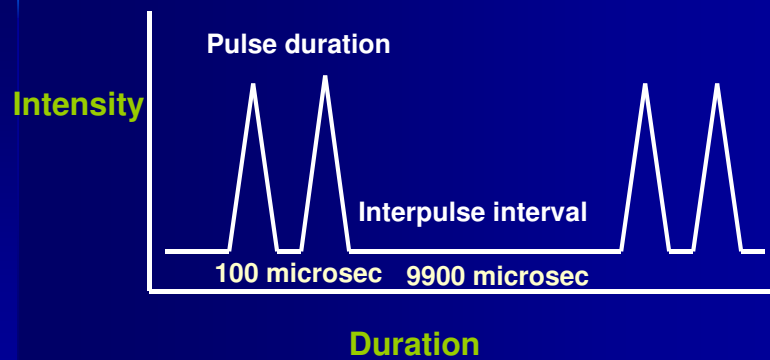
- TES
  - D/C
  - A/C
  - Monophasic Pulsed
  - Asymmetrical Biphasic Pulsed Current
  - Symmetrical Biphasic Pulsed Current

## ELECTRICAL STIMULATION

- Not flow of 'electrons' into tissue (force)
- The path of least resistance
- Parameters:
  - Frequency
  - Pulse duration
  - Interpulse interval
  - Amplitude

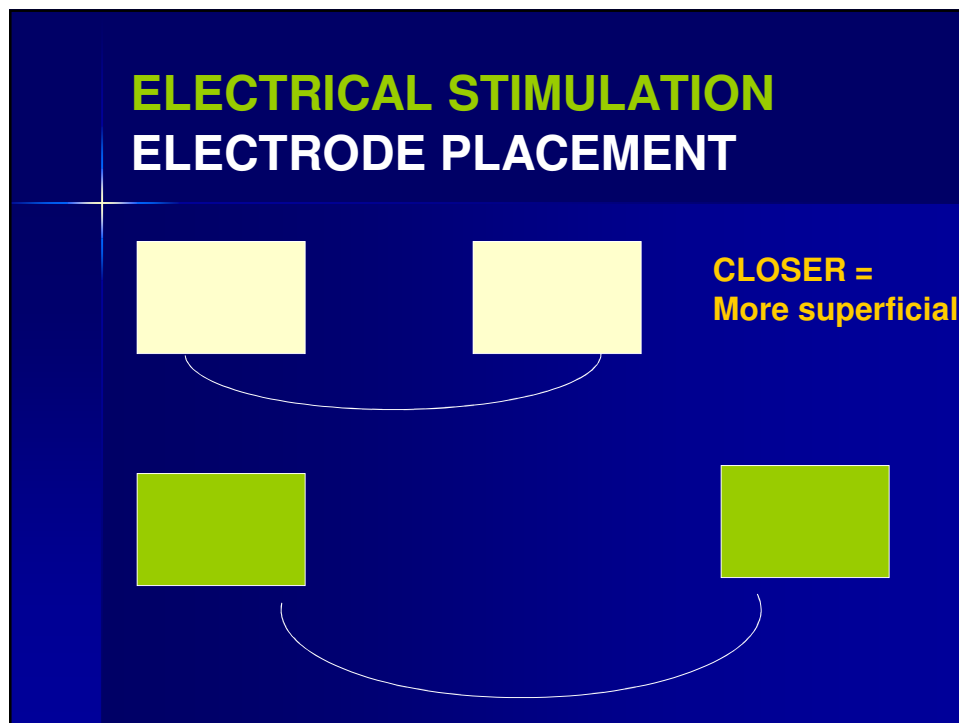
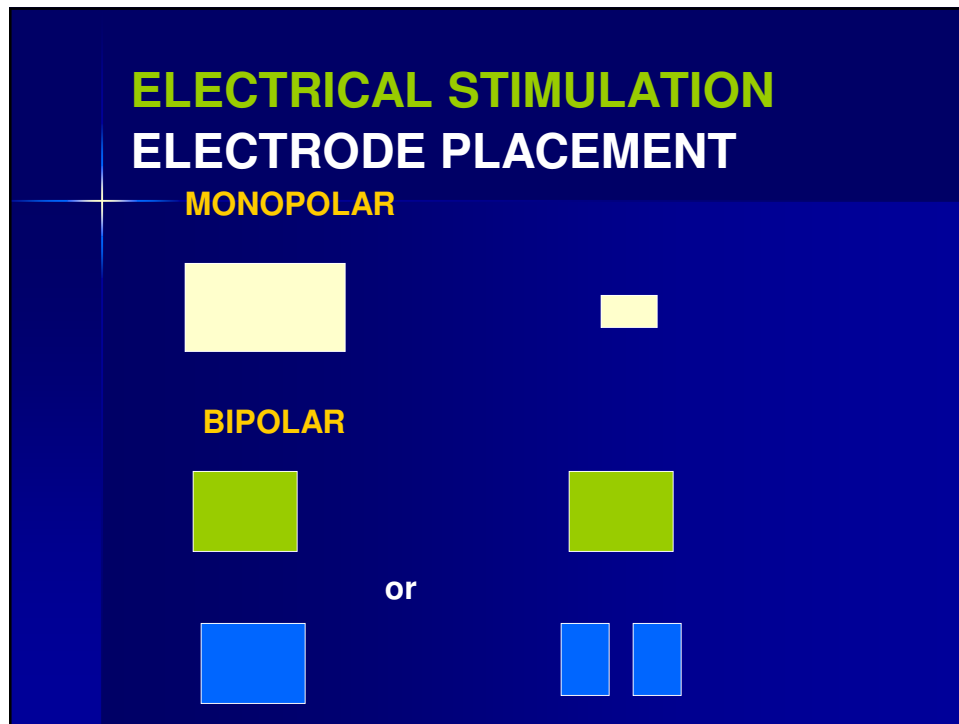
**\*\*REMEMBER THE STRENGTH-DURATION CURVE!**

## HVPC



## HVPC

- **Waveform:** Twin peak monophasic
- **Frequency:** ~ 1-200 Hz
- **Pulse Width:** ~ 5-65 microsec (fixed)
- **Peak Current:** High
- **Interpulse Interval:** Long
- **Total Current:** Very low (~ 1.5 mA)
- **Polarity:** Yes



## ELECTRICAL STIMULATION

- **Effects of E-Stim on Wound Healing**
  - Bioelectrical Potential/Skin Battery
  - Galvanotaxis
  - Stimulate new tissue formation
  - Collagen organization & wound strength
  - Edema reduction
  - Change in blood flow
  - Reoxygenation
  - Antibacterial

## ELECTRICAL STIMULATION

- **Bioelectric potential / skin battery**
  - Normal skin battery in intact skin 10-60 mV; avg 23.4 mV Foulds & Barker 1983
  - Wound:
    - electrical 'leak'; 'positive injury current'
    - Likely aids in healing Kloth 2005
    - sustained by occlusive dressings Cheng et al 1995
    - reduced and then eliminated by new epithelium Jaffe & Venable 1984

## ELECTRICAL STIMULATION - Galvanotaxis

PHASE	EFFECTS	CELL & POLARITY	CURRENT POLARITY	REF
Inflamm.	Phagocyto. Autolysis	Macrophage (-) Neutrophil (-)	DC (+) DC (+) PC (+) DC (-)	Orida Fukushima Everhardt Dineur
Prolifer.	Fibroplasia	Fibroblast (+)	PC (-) DC(-)	Bourguignon Canaday
Remodel.	Wound contraction Epithelializ.	Myofibroblast (+) Keratinocyte (+) Epidermal (-)	PC (-) DC(-)	Stromberg Nishimura

Modified from Table 1. P.26 Kloth 2005

Galvanotaxis - movement of cells toward opposite polarity/ away from same polarity

## ELECTRICAL STIMULATION

### ■ Stimulate new tissue formation

– Studies have shown that Estim facilitates the synthesis of new tissue

- Collagen synthesis (pigs) Alvarez '83
- ATP & protein synthesis (rats) Cheng et al '82
- Fibroblast (culture- HVPC) Bassett & Herrmann 1968  
Bourguignon & Bourguignon '87;
- Closure rate, collagen localization \*diabetic mice  
Thawer et al 2000



## ELECTRICAL STIMULATION

### ■ Collagen Organization & Wound Strength

– Healing tissue exposed to Estim is more 'organized'

- Collagen parallel to skin (pigs) Assimacopoulos '86
- Brown M et al (1995)

## ELECTRICAL STIMULATION

### ■ Growth factors

– Studies have shown that Estim stimulates the production of growth factors.

- Corneal epithelial cells Zhao et al '99
- Osteoblasts, Zhuang et al '97
- Fibroblasts, Falanga et al '97
- PDGF (Platelet derived growth factor) diabetic mice Thawer & Houghton 2000

## ELECTRICAL STIMULATION

### ■ Increased Capillary Density

- 43.5 % increase in capillary density in venous leg ulcers of 15 patients with wounds that were unchanged after several months of standard care

Monophasic PC daily for mean of 38 days; 140 microsec PW

Junger et al '97

- Angiogenesis resulted in re-epithelization 2 days earlier (burns - pigs)

Greenberg et al, 2000

## ELECTRICAL STIMULATION

### ■ Antibacterial

- Numerous in vitro & in vivo studies show microamp levels of DC either kill or inhibit proliferation of common wound pathogens

Kloth 2005

- Cathode, E. Coli (culture) Rowley '72
- Cathode, infection (rabbit) Rowley '72
- Antibacterial (human) Wheeler et al '72
- HVPC, bacteria in culture Kincaid & Lavoie '89
- HVPC, E Coli, Pseudo, SA Szuminsky '94
- Ong et al '94
- Laatsch '95

## ELECTRICAL STIMULATION

### ■ Edema Reduction

- There are mixed results regarding the reduction of edema by Estim
  - HVPC (+), cathode Mendel & Fish '91/92
  - HVPC (+) Taylor et al '92
  - HVPC (+) Bettany et al '90
  - Pulsed (-) Karnes et al '92
  - HVPC (-) Mohr et al '87
  - mono & bi pulsed current (-) Cosgrove '92
- \* best early; temporary effect

## ELECTRICAL STIMULATION

### ■ Reoxygenation

- Cells need O<sub>2</sub> for tissue repair and become inefficient in anoxic environments. Estim facilitates a temporary increase in local tissue O<sub>2</sub> tension. Kloth 2005
  - TcPO<sub>2</sub> in diabetic pts Dodgen et al '87
  - TcPO<sub>2</sub> Edwards et al '92 Mawson et al '93
  - TcPO<sub>2</sub> in paraplegics Gagnier et al '88

## ELECTRICAL STIMULATION

### ■ Change in blood flow

- Studies have shown Estim enhances blood flow
  - mm contraction around wound induce changes in bf Thomas et al '92
  - paraspinal stim increased bf, skin temp & healing Augustinsson et al '85
  - TENS to acupuncture pts caused peripheral vasodilation Kaada '82
  - survival of skin flaps in humans Lundeberg et al '98
  - survival of skin flaps in animals
  - TENS 20 mA 80 pps X 3 days (rats) Kjartson et al '93
  - Monophasic PC 35 mA, 128 pps 140 microsec, 30 min 2X/day Im et al, '90

## ELECTRICAL STIMULATION

### ■ Summary of effects of E-stim on wound healing

- **Immune System:** inhibit bacterial growth
- **Tissue Repair:** Migration, galvanotaxis, cell proliferation, growth factors
- **Oxygen Delivery:** Edema reduction, improved blood supply

## ELECTRICAL STIMULATION

- Stimulation Parameters
  - Waveform: net charge (HVPC)
  - Polarity: based on stage of healing
  - Frequency: 50-100 Hz
  - Intensity: sensory/submotor
  - Treatment time: 30-60 min
  - Treatment schedule: daily-3X/week with dressing changes

## ELECTRICAL STIMULATION

- Application preparation
  - Informed consent
  - Sensation test: sharp/blunt

## ELECTRICAL STIMULATION

### ■ Contraindications

- Malignancy
- Osteomyelitis
- Metal residues of iodine or silver in wound
- Pacemaker
- Untreated DVT
- Severe arterial insufficiency
- Pregnancy (local CI)
- \* Canadian Decision Making Guide to be distributed through CPA in Nov 2010
- \*Caution with impaired sensation, cognition, PVD

# Physiotherapy








CANADA

ELECTROPHYSICAL AGENTS  
Contraindications And Precautions: An Evidence-Based Approach To Clinical  
Decision Making In Physical Therapy



VOLUME 62 NUMBER 5 SPECIAL ISSUE 2010 ISSN-0300-0508 E-ISSN-1708-8313

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	Resources % (n = 11)	Can/US %	APA	CSP	Adverse Reaction**	Research Evidence**	Recommendation	For Details See
Impaired cognition or communication	9	57 (n = 7)	P	C	Minor	Moderate	 TENS  NMES/HVPC	4-11
Recent fracture or suture Osteoporosis	18	N/A	N/A	N/A	Moderate	Moderate	 NMES  HVPC/TENS	4-13
Seizure/epilepsy	9	N/A	N/A	C	Moderate	Moderate		4-14
<b>Implants</b>								
Electronic implant	100	86 (n = 7)	C-local	C	Serious	Moderate		4-1
Metal implant	S	29 (n = 7)	N/A	S	Minor	Low		4-12

**4-9 Impaired Circulation**

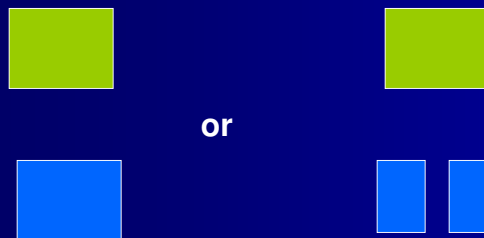
<b>Recommendation</b>	E-stim may be beneficial in the presence of moderate arterial disease. In the presence of severe arterial disease, however, electrical current can induce ischemia, exacerbate pain, and potentially damage fragile tissue.
 <b>NMES, TENS</b>	
 <b>HVPC</b>	HVPC/TENS can be applied by experienced clinicians to improve wound healing and reduce claudication in people with arterial disease.
<b>Rationale</b>	Increasing cellular activity increases metabolic demand; in cases of severely compromised circulation, the demand may exceed oxygen supply, resulting in increased pain. Continued treatment may lead to tissue ischemia and necrosis. Deficiency in either arterial or venous circulation is associated with skin deterioration and edema. Applying E-stim electrodes over compromised skin may cause skin breakdown, which is difficult to heal and can potentially lead to chronic wounds. Intact skin offers greater resistance to current flow than does broken skin; uneven current flow under electrodes as a result of skin loss or damage increases the risk of tissue burns.
<b>Research Evidence LOW</b>	Electrically induced improvements in regional blood flow and tissue oxygenation have been documented in people with diabetes, spinal-cord injury, and chronic wounds. <sup>27,40-44</sup> NMES applied to calf muscles improved functional capacity of people with claudication due to advanced arterial disease. HVPC and A-TENS have been used safely to treat patients with arterial insufficiency. <sup>41-44</sup>

## ELECTRODE PLACEMENT

### MONOPOLAR



### BIPOLAR



or

## ELECTRICAL STIMULATION

### ■ Monopolar Electrode Set-up

#### – *Active:*

- placed in ulcer; sterile/single use eg. Saline soaked gauze covered by metal foil, hydrogel gauze

#### – *Dispersive:*

- 2X size of active on intact skin proximal to wound (~ 10-20 cm away, further away for deeper wounds); eg. Self adhesive or carbon coated covered with sponge





## CLINICAL RESEARCH EVIDENCE

	Strength Of Evidence	# of reports	(+) RCT	(+) NC	(-) RCT	(-) NC
<b>E-Stim</b>	<b>A</b>	<b>25</b>	<b>10</b>	<b>15</b>	<b>-</b>	<b>-</b>
<b>US</b>	<b>B</b>	<b>16</b>	<b>8</b>	<b>4</b>	<b>4</b>	<b>-</b>
<b>UVC</b>	<b>B</b>	<b>6</b>	<b>2</b>	<b>4</b>	<b>-</b>	<b>-</b>
<b>Laser</b>	<b>C</b>	<b>9</b>	<b>-</b>	<b>6</b>	<b>3</b>	<b>-</b>

### A Retrospective Study of High-Voltage, Pulsed Current as an Adjunctive Therapy in Limb Salvage for Chronic Diabetic Wounds of the Lower Extremity

Jeremy J. Burdge, MD; Jodi F. Hartman, MS; and Michelle L. Wright, BS



Figure 2: A pre-treatment photograph of the foot of a 61.9-year-old man with controlled diabetes, neuropathy, and infection who had a UT 1B forefoot plantar ulcer for approximately 9 months (A). Before beginning HVPC therapy, the patient was discouraged by the ineffectiveness of previous treatment and soaked the wound in extremely hot water containing Epsom salt. After suffering third-degree burns of the foot from the water temperature, the patient developed a UT 1B heel ulcer (B and C). After 25 HVPC treatments, both wounds healed at 8.9 and 12.6 weeks, respectively, and have not recurred at a most recent follow-up of 5 months (D and E).

Ostomy Wound Mngt 2009

## SUMMARY - ESTIM

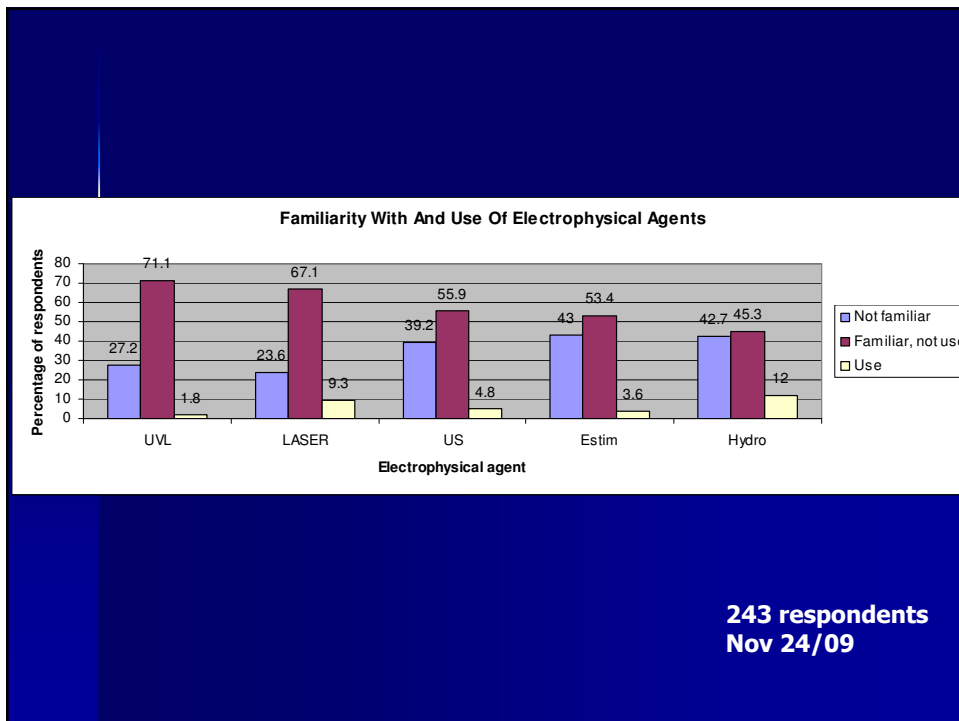
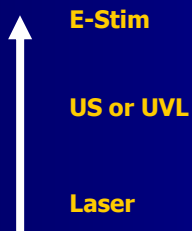
- Electrical stimulation plus standard wound care accelerates the healing rate of chronic wounds significantly faster than standard wound care alone. Kloth 2001
- Estim recommended for Rx of chronic pressure ulcers. ACHPR & Dolynchuk 2000
- 2002- Estim approved for payment by Centers for Medicare & Medicaid Services in US for Rx of pressure ulcers & wounds of L/E caused by venous & arterial insufficiency & diabetes Kloth 2005

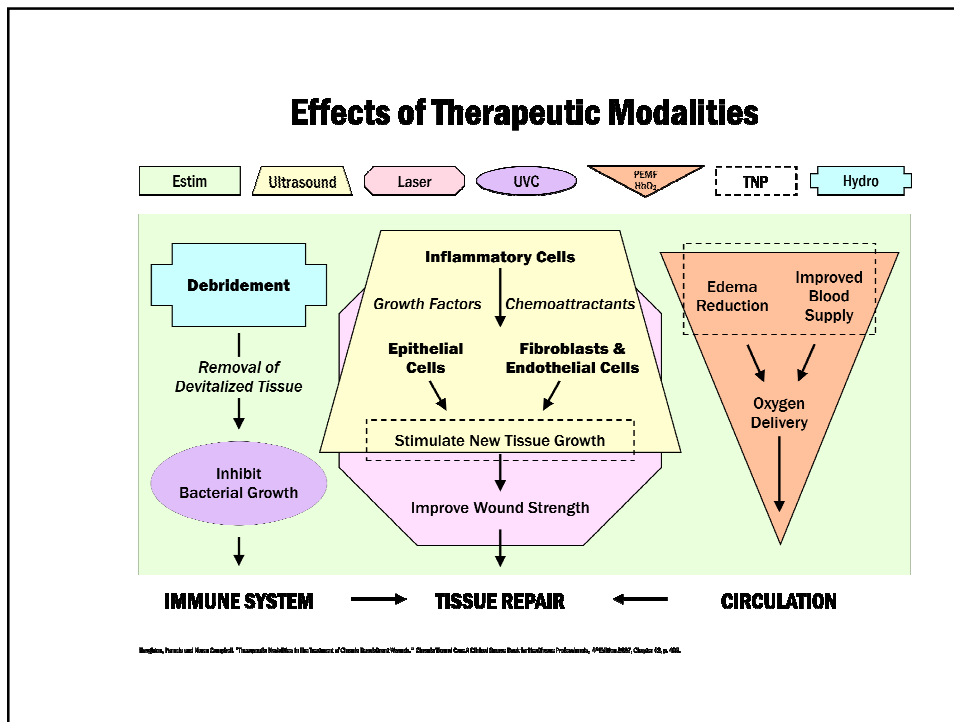
## SUMMARY

- **Pressure ulcers**
  - Estim>US or \*UVC (\*if infected) \*LASER not recommended
- **Diabetic ulcers**
  - Estim > US
- **Arterial ulcers**
  - Estim \*LASER not recommended
- **Venous ulcers**
  - US/Estim \*LASER not recommended
- **Surgical wounds**
  - Estim> US, LASER

# SUMMARY

- The literature supports the adjunctive use of EPAs for wound healing





## QUESTIONS

■ [Alison.hoens@ubc.ca](mailto:Alison.hoens@ubc.ca)