Introduction to Lasers in Dermatology
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• Please no photos during the presentation
• Patient privacy needs to be protected
Lasers Applications in Medicine

• *Dermatology*
  – Blood vessel lesions
  – Pigmented (Brown) Lesions
  – Tattoos
  – Laser Hair Removal
  – Skin Resurfacing
  – Skin Rejuvenation
  – Acne
  – Vitiligo
Lasers Applications in Medicine

- Neurosurgery
- Podiatry
- General Surgery
- Gynecology
- Ophthalmology
Laser Effect on Biological Tissue

Depends on tissue properties
Function of laser parameters
Details are not fully understood
Tissue Properties

optical
light distribution

thermal
heat transfer

mechanical
stress propagation
Laser Parameters

Things a surgeon can control

- Wavelength
  Determines penetration depth
  “targets chromophore”
- Pulse Duration
  How long the tissue is heated
- Power
  Energy deposition/Heating rate
- Use of Epidermal Cooling
Objective of Laser Skin Surgery

Target a selected light absorbing chromophore in human skin without damaging surrounding tissue
• Blood vessel lesion improvement
• Significant incidence of scarring especially in young children
Theory of Selective Photothermolysis

- Laser energy preferentially absorbed by one structure in tissue
  - Melanin, dermis, blood, tattoo ink, etc
- Surrounding tissue has low absorption
- Selective absorption of radiant energy
- Selective heating/destruction of tissue

Anderson R, Parrish J, Science 1983; 220:524-527
selective

Only chromophores absorb light

Lysis

Photothermal
• Two parameters central to this concept
  – Wavelength
  – Pulse Duration

Anderson R, Parrish J, Science 1983; 220:524-527
Wavelength

• Laser wavelength must approximate an absorption peak of the targeted chromophore in relation to other optically absorbing molecules.

• Wavelength also determines the depth to which light penetrates with sufficient energy to effect tissue change.
Chromophores in human skin - absorption spectra of hemoglobin, melanin and water
Selective Photothermolysis

• Pulse duration should be on the order of the thermal relaxation time (TRT) of the target

• Thermal relaxation time is the duration required for the heat generated by absorbed light energy within the target chromophore to dissipate to 50% of its value immediately after laser exposure
Thermal Relaxation Time

- Directly related to the size of the target
- Inversely related to heat diffusion of the tissue
<table>
<thead>
<tr>
<th>Target</th>
<th>Size</th>
<th>$\tau_r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>microvessel</td>
<td>10 $\mu$m</td>
<td>90 $\mu$s</td>
</tr>
<tr>
<td>blood vessel</td>
<td>200 $\mu$m</td>
<td>5 ms</td>
</tr>
<tr>
<td>tattoo pigment</td>
<td>0.5-100 $\mu$m</td>
<td>20 ns-3 ms</td>
</tr>
<tr>
<td>melanosome</td>
<td>0.5-1.0 $\mu$m</td>
<td>20-40 ns</td>
</tr>
<tr>
<td>melanocyte</td>
<td>7 $\mu$m</td>
<td>1 $\mu$s</td>
</tr>
</tbody>
</table>
Pulse Duration of Commercially Available Pulsed Dye Lasers

- 450 microseconds
- 1500 microseconds
- 1500-40,000 microseconds
Longer Pulse Durations

**PURPURA**

- Laser Bruise or Purpura
- Ruptured Vessels Causing the Purpura

**NO PURPURA**

- No Purpura
- Coagulated Vessels
Selective photothermolysis significantly improved treatment outcome
However, challenges remained:
  Multiple treatments required
  Incomplete lesion removal
  Treatment of darker skin types
  Treatment discomfort
Problem: Nonspecific epidermal (melanin) absorption

Answer: Epidermal Cooling
Chromophores in human skin - absorption spectra of hemoglobin, melanin and water

- Hemoglobin
- Melanin
- Water

Wavelength (nm)

- 514/532
- 577/595
- 694
- 755
- 1064
- 2940
- 10600

Sources:
- Argon
- KTP
- Pulsed Dye
- Ruby
- Alexandrite
- Nd:YAG
- Er:YAG
- Carbon dioxide
Cooling the Superficial Skin Layers

Prevents epidermal injury
Leaves the dermal target susceptible to laser induced thermal injury
Cryogen Spray Cooling Device
Contact Cooling Devices
Air Cooling Device
Epidermal Cooling

- Allows the use of higher fluences
- Allows safe treatment of darker skin
- Decreases treatment discomfort
Lasers Applications in Medicine

• *Dermatology*
  – Vascular lesions
  – Select Pigmented Lesions
  – Tattoos
  – Laser Hair Removal
  – Skin Resurfacing
  – Skin Rejuvenation
  – Acne
  – Vitiligo
Laser Treatment of Vascular Skin Lesions
Laser Treatment of Vasculature

- Chromophore: Oxyhemoglobin (blood)
- Pulse Duration: Variable (1-10 milliseconds)
Immediate blood vessel hemorrhage after pulsed dye laser treatment in an animal model
Laser Treatment of Pigmented Lesions
Laser Treatment of Pigmented Lesions

- Chromophore: Melanin
- Pulse Duration: Very Short (Q-switched)
Tattoo Removal
Tattoo Removal

- Target Chromophore: Tattoo pigment
- Pulse Duration: Very Short (Q-switched)
• Photothermal and Photoacoustic
• Wavelength selection based on color
• Shock waves break up tattoo dye and then blood cells clear away

Laser Hair Removal
Laser for Hair Removal

- Ruby Laser ($\lambda = 694$ nm)
- Alexandrite Laser ($\lambda = 755$ nm)
- Diode Laser ($\lambda = 800$ nm)
- Long Pulsed Nd:YAG Laser ($\lambda = 1064$ nm)
- Pulsed Filtered Flashlamp ($\lambda = 590 - 1200$ nm)
Laser Hair Removal

- Target Chromophore: Hair Shaft Melanin
- Pulse Duration: Long (20-50 milliseconds)
Laser Skin Resurfacing

- CO\textsubscript{2} and Er:YAG lasers
- Target: tissue water
- Tissue ablation
Formation of New Collagen
Methods to induce collagen remodeling

Ablative

Non-ablative

Fractional Photothermolysis

Photodynamic Therapy (PDT)

- PDT is a drug-device combination
- The topical drug is activated by appropriate light
- Requires
  - Photosensitizer
  - Light
  - Oxygen
- ALA is applied topically to the skin and converts to Protoporphyrin IX, a naturally-occurring, powerful photosensitizer

- ALA is preferentially absorbed by fast-growing cells, e.g. AK’s, sebaceous glands, sun-damaged cells
PDT

- Photosensitizer is applied to desired treatment areas
- Wait
- Photosensitizer washed off
- Laser or light source treatment
- Photoprotection
Beckman Laser Institute