VASCULAR ASPECTS OF PRESSURE ULCERS

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Problem

Ponder

Potentiate

Pursue

Pin-it-Down

Party
Pressure Ulcer

Epidermis

Dermis

Fat

Compressed Vasculature

Bone

Muscle
Blood Flow Reduction

- Sustained
- Intermittent

Pressure

- How Much?
- How Long?
- Where?

Adaptation During Load?
Off-Load Interval Recovery?
Recovery Potential?

Tissue Injury and Breakdown

Moisture-Temperature-Nutrition-Vascular Status-Age
COMMON PRESSURE ULCER SITES

After Maklebust & Sieggreen, 1996
Skin

Epidermis

Dermis

Artery

Arteriole

Nerve

Pore

Duct

Capillary

Fat

Hair
Tissue Loading

- Force
- Epidermis

- Compression
- Pressure
- Resistance

Capillary Blood Flow

- $P_0(+)$

- Distortion
- Twisting
- Kinking

Reduced Blood Flow

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Tissue Effects

- Reduced Blood Flow
- Force
- $O_2 (-)$
- $CO_2 (+)$
- $H_2O (+)$
- Intravascular Changes

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Epidermis

Defensive Measures

Compensatory Vascular Responses

- Recruitment
- Vasodilation

Collateral Feed
Detection of Blood Flow Changes

LASER-DOPPLER

Low Resting Flow

Occluded Flow

Restored Flow
BLOOD PERFUSION BY LASER-DOPPLER IMAGING

Forearm Heated to 44°C
Trochanter Perfusion
Subject B - Static Support

Subject: 68”, 200 lb, 64 yrs, hypertensive female

Laser-Doppler Flowmetry Study     Female, >60

Supine
Hip-Down
Supine
Trochanter Perfusion
Subject B - Dynamic Surface

Subject: 68”, 200 lb, 64 yrs, hypertensive female.
Support Surface Impact on Trochanter Blood Perfusion

LD Perfusion (a.u.)

- Dynamic surface
- Static surface

* p=0.02, ** p=0.01

Error bars are +/- 1 sem

Pre-Load Baseline
0-15 min Loading
45-60 min Loading

Error bars are sem
Heel LDI Images Before, During and After Loading

40” Supine Lying

Hyperemia
Overall Blood Perfusion Sequential Changes

N=11 Subjects
10 mm x 10 mm area
mean +/- 2 sem
Protocol Sequence

History, Demographics & Vascular Assessments

Subject Placed Prone - 10-min rest interval

Unloaded Heel Perfusion (Laser-Doppler Imaging, LDI)

10-min Load Duration
- Heel loaded - 30 mmHg
  - Load removed
  - Sequential LDI Scans until perfusion recovery
  - Repeat: 60, 120, 140 mmHg
  - Heel heated (44\(^\circ\)C-5-min) & post-heat LDI scans

120 mmHg Load
- Heel loaded - 2.5 minutes
  - Load removed
  - Sequential LDI Scans until perfusion recovery
  - Repeat: 5, 10, 20 minutes
  - Heel heated (44\(^\circ\)C-5-min) & post-heat LDI scans

One Week Apart
Post-Loading Laser Doppler Images

Baseline

Sequential LDI scans after load removal 1/min

120 mmHg for 10-min

+1

+2

+3

+4

+5

+6

+7
Post-load Hyperemia appears to peak after 5-10 minutes of loading @ 120 mmHg.

Post-load Hyperemia precipitously increases between 60-120 mmHg when loaded for 10-min.
### RECOVERY

**Recovery Time increases up-to a load duration of about 10 minutes**

**Graph (A)**
- Fixed Load (120 mmHg)
- **Tr** = 2.58D^{0.36}
- \( r^2 = 0.419, p < 0.001 \)
- N=14, n=56

**Graph (B)**
- Fixed Duration (10 minutes)
- **Tr** = 0.12P^{0.79}
- \( r^2 = 0.600, p < 0.001 \)
- N=14, n=56

Recovery Time increases up-to a load magnitude of about 120 mmHg
Hyperemia Depends on Combined Pressure & Duration

Each point is mean of all subjects

\[ y = 0.338 + 0.006x - 2E-06x^2 \]

\[ R^2 = 0.802 \]
Recovery Depends on Combined Pressure & Duration

Each point is mean of all subjects

\[ y = 1.32 + 0.0053x - 1E-06x^2 \]

\[ R^2 = 0.844 \]
PRE- LYING BLOOD PERFUSION

STATIC SURFACE

DYNAMIC
15 cycle/hr
TWO-HOUR SUPINE LYING

STATIC SURFACE

DYNAMIC 15 cycle/hr
Jump Start

RESEARCH

Chug Along

Solve the
Pressure

Tissue - Vascular Compression & Distortion

Blood Flow Reduction or Cessation

Tissue & Vascular Deficits, Injury and Breakdown
Perfusion Responses by Key Intervals

N=11 subjects
10 x 10 mm Area
(mean +/- sem)

- PRE-LOAD
- DURING LOAD
- OFF-LOADED

* denotes significant difference
<table>
<thead>
<tr>
<th>Subject</th>
<th>Avg.</th>
<th>sem</th>
<th>Range</th>
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</thead>
<tbody>
<tr>
<td>Height (inches)</td>
<td>62.8</td>
<td>±0.7</td>
<td>58 – 69</td>
</tr>
<tr>
<td>Weight (lbs.)</td>
<td>144.7</td>
<td>±7.9</td>
<td>82 – 208</td>
</tr>
<tr>
<td>BSA (kg/m²)</td>
<td>1.67</td>
<td>±0.45</td>
<td>1.32 – 2.04</td>
</tr>
<tr>
<td>Age (years)</td>
<td>70.4</td>
<td>±1.9</td>
<td>60 – 85</td>
</tr>
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N = 20 women

Laser-Doppler Flowmetry Study