PRESSURE AND BLOOD FLOW LINKAGES AND IMPACTS ON PRESSURE ULCER DEVELOPMENT

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Pressure

Tissue - Vascular Compression & Distortion

Blood Flow Reduction or Cessation

Tissue & Vascular Deficits, Injury and Breakdown

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Blood Flow Reduction

Pressure

Sustained Intermittent

δ

Blood Flow Reduction

- How Much?
- How Long?
- Where?

ε

Tissue Injury and Breakdown

- Αδαπτατιον Δυρινγ Λοαδ?
- Οφφ-Λοαδ Ιντερσανα Ρεχουερν?
- Ρεχουερν Ποτεντιαλ?

Moisture-Temperature-Nutrition - Vascular Status-Age

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COMMON PRESSURE ULCER SITES

After Maklebust & Sieggreen, 1996
Layers (Stratum) of the Epidermis

- Keratinocyte Maturation
- Basal Stem Cells
- Melanocytes
- Langerhans cells
- Dead Keratinocytes
- Capillary
- O$_2$

Dermis

Corneum
Lucidum
Granulosum
Spinosum
Basale
Skin

Epidermis

Dermis

Arteriole

Artery

Fat

Nerve

Capillary

Duct

Pore

Hair
Epidermis

O₂

O₂

O₂

CO₂

H₂O

Vein

Lymphatic

Skin Circulation

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Muscle Cells
Endothelial Cells
Blood Flow Increases
Vasodilation

Arterioles Supply Tissue Needs

Relaxed

Muscle Cells
Contracted

Proective

Contract Stuff

Endothelial Cells

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Unmask Early Endothelial Dysfunction

Blood Vessel Responds to Natural Substances
Endothelial Cell Functional Changes

Arm Blood Flow

Blood Pressure
- Normal
- High

AGE

< 30 | 45-60 | > 60

< 30 | 45-60 | > 60
Transmural Pressure Effects Lumen Size

Blood Flows in Vessel Lumen

Connective Tissue “Rubber-Band”

Muscle Cells

\( P_0 \)

\( P_i \)

\( R \)
Local Factors Affecting Blood Flow

- Ενδοτηκελιαλ Φυσικτιον
- Μεχχανικαλ Φορχες
- Τισσιντ Ενσιρονμενε

\( P_0 \)

\( O_2 \)

\( P_i \)

\( CO_2 \)
Epidermis

- Compression
- Pressure
- Resistance

Capillary Blood Flow

Po(+)

Distortion
Twisting
Kinking

Reduced Blood Flow

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Tissue Loading
Tissue Effects

Epidermis

Force

$O_2 (-)$

Intravascular Changes

$XO_2 (+)$

$O_2 (-)$

$H_2O (+)$

Reduced Blood Flow

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Epidermis

Defensive Measures

Convective Flow

Collateral Feed

Recruitment

Vasodilation

Compensatory Vascular Responses

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Detection of Blood Flow Changes

Low Resting Flow

Occluded Flow

Restored Flow

0 500
THERMAL IMAGING BY INFRARED

Фореарμ Σκιν ΒΑΣΕΛΙΝΕ

Heat off for 1-Minute

Heat off for 2-

Heat off for 7-Minutes

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BLOOD PERFUSION BY LASER-DOPPLER IMAGING

Forearm heated to 44°C
Progressive Flow Compensation

Flow Response During Trochanter Loading

Flow

Hip-Down Loading

1-Hour

Hip-down loading on a multi-segmental dynamic surface
N=20 Women >= age 60. Mayrovitz et al., 1997
Similar findings: Xakellis et al., 1993 and Frantz et al., 1989
Implications for Ulcer Development

Absence of Flow Adaptation Under Load was Associated with Ulcer Development

Sanada et al., 1997
- 24 patients undergoing surgery
- 18 Abdominal - 6 spinal disk
- LDF @ sacral or iliac prominence

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Myogenic Compensation

Flow Response During Short-Term Heel Loading

- Flow
- Pressure
- 5 mmHg
- 15
- 35
- 45
- 2-min
- 55
- 65

Myogenic Adaptation
Myogenic Overload

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Heel Hyperemia After Local Loading

Temporal Response

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>LDI Perfusion</th>
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<tbody>
<tr>
<td>0</td>
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<tr>
<td>2</td>
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<td>800</td>
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<td>10</td>
<td>1000</td>
</tr>
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120 mmHg

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BLOOD FLOW RESPONSE TO OFF-LOADING

Duration of Heel Loading (minutes)

0 5 10 15 20

Heel LDI Perfusion (Hyperemic/Baseline)

Load = 120 mmHg
N = 14 Females

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BLOOD FLOW RESPONSE TO OFF-LOADING

Time After Load Removal (minutes)
0 1 2 3 4 5 6 7 8 9 10
Heel LDI Perfusion (Hyperemic/Baseline)

Load Duration (min)
- 2.5
- 5.0
- 10

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PEAK HYPEREMIA RESPONSE

% of Maximum Thermal Response

Load Duration = 10 minutes
Subjects = 14 Females

Heel Blood Perfusion
(Percent of Heated Maximum)

Heel Load (mmHg)

Load Duration = 10 minutes
Subjects = 14 Females

% of Maximum Thermal Response

Heel Blood Perfusion
(Percent of Heated Maximum)

Heel Load (mmHg)

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HYPEREMIA RECOVERY TIME

Load Duration = 10 minutes
Subjects = 14 Females
PRE-ΔΥΣΤΙΧ ΒΛΟΟΔ ΠΕΡΦΥΣΙΟΝ

ΣΤΑΤΙΧ ΣΥΡΦΑΚΕ

ΔΥΣΝΑΜΙΧ
15 χψχλε/ηρ

HN Μαυροποιτς 1998
ΤWO-HOUR ΣΥΠΙΝΕ ΛΨΙΝΓ

ΣΤΑΤΙΧ ΣΥΡΦΑΧΕ

ΔΥΝΑΜΙΧ 15 χψχλε/ηρ

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BLOOD FLOW RESPONSE TO OFF-LOADING

Duration of Heel Loading (minutes)

Heel LDI Perfusion (Hyperemic/Baseline)

Load = 120 mmHg
N = 14 Females

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PEAK HYPEREMIA RESPONSE

Relative to Average No-Load Baseline

Load Duration = 10 minutes
Subjects = 14 Females

Heel Blood Perfusion
(Ratio of Peak to Baseline)

Heel Load (mmHg)

0 30 60 90 120 150
HEEL HYPEREMIA RECOVERY TIME

Duration of Heel Loading ($T_{\text{Load}}$ in minutes)

0 5 10 15 20

Perfusion Recovery Time ($T_{R}$ minutes)

3
4
5
6
7
8
9
10

Load = 120 mmHg
N = 14 Females

$T_{R} = 3.40 + 0.27 \ T_{\text{Load}}$

$r^2 = 0.445, p < 0.001$
HEEL HYPEREMIC PEAK RESPONSE

Duration of Heel Loading (minutes)

0 5 10 15 20

Heel Blood Perfusion
(Percent of Heated Maximum)

40
50
60
70
80
90
100

Load = 120 mmHg
N = 14 Females