Skin Profusion-
What it Takes to Keep it Alive

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University of Toronto
Clinical Editor, Advances in Skin & Wound Care

Dr. Sibbald’s Potential Conflicts of Interest
Clinical Editor- Advances in Skin & Wound Care

<table>
<thead>
<tr>
<th>Company/ Agency</th>
<th>Paid Lecturers</th>
<th>Advisory Board Members</th>
<th>Research Participants</th>
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<td>RNAO- Registered Nurses</td>
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<td>Association of Ontario</td>
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<td>Galderma</td>
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<td>Valeant</td>
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<td>Abbott/ Abbvie</td>
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<td>MH-CCAC, MHLTC, HQO = Province of Ontario Government</td>
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<td>Eli Lilly Canada Inc.</td>
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<td>Ferris Manufacturing Comp</td>
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Participants will:

- Evaluate and manage Lower Limb Peripheral Vascular Disease related to Pressure Injury
- Examine the Effect of external and internal factors on pressure injury associated skin profusion & skin compromise
- Assess treatment options to optimize pressure injury associated skin profusion

How to assess the circulation of a heel pressure injury post hip replacement?
How to assess lower limb circulation?

Palpate for dorsalis pedis or posterior tibial pulse (foot pulse)

TREAT THE CAUSE

Perform an Ankle Brachial Pressure Index (ABPI, ABI) if indicated

• Foot pulses not palpable
• Consider transcutaneous oxygen tension measurements
VASCULAR SUPPLY AND HEALING ABILITY
(SIBBALD ET AL WBP 2015)

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<tbody>
<tr>
<td>Palpable pulse</td>
<td>&gt;80 mm Hg</td>
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<tr>
<td>Ankle-brachial</td>
<td>&gt;0.5 and &lt;1.3</td>
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<tr>
<td>pressure index</td>
<td></td>
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<tr>
<td>(ABPI)</td>
<td></td>
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<tr>
<td>Transcutaneous</td>
<td>&gt;30 mm Hg</td>
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<tr>
<td>$O_2$ tension</td>
<td></td>
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<tr>
<td>Toe pressure</td>
<td>&gt;55 mm Hg</td>
</tr>
<tr>
<td>Audible hand</td>
<td>Triphasic,</td>
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<tr>
<td>held Doppler</td>
<td>Biphasic Sound</td>
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© 2013 IWCC
AUDIBLE HAND HELD DOPPLER ULTRASOUND DETERMINES RELIABLE & INEXPENSIVE EXCLUSION OF SIGNIFICANT PVD
ALAVI A, SIBBALD RG, NABAVIZADEH R, VALAEI F, COUITS P, MAYER D VASCULAR. 2015 JAN 27. PII: 170838114568703. EPUB AHEAD OF PRINT

• Accuracy audible hand held Doppler ultrasound (AHHD) to identify PVD
• 200 patients, 379 legs
• All had ABPI, toe pressures at certified vascular lab (Gold Standard)

<table>
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<tr>
<th>Criteria</th>
<th>Meaning</th>
<th>Result PT/ DP</th>
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<tr>
<td>Specificity</td>
<td>No PVD</td>
<td>98.6%/97.8%</td>
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<tr>
<td>Sensitivity</td>
<td>PVD identified</td>
<td>37.5%/30.19%</td>
</tr>
<tr>
<td>+ Pre. Value (PPV)</td>
<td>Abn. AHHD + PVD</td>
<td>81.2%/72.75%</td>
</tr>
<tr>
<td>- Pre. Value (NPV)</td>
<td>Normal AHHD/no PVD</td>
<td>90.91%/88.10%</td>
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**Conclusion:** AHHD reliable, simple, rapid, inexpensive bedside exclusion test PVD in Diabetic/ non-diabetic subjects

**No Smoking: Double indemnity**

• Every cigarette will decrease the circulation in the leg or foot up to 30% for an hour or increase sympathetic tone for 8 hours

*Cigarette smoking decreases tissue oxygen.* — *Jensen JA - Arch Surg* - 01-SEP-1991; 126(9): 1131-4
ANGIOSOME THEORY

- Proposed by Attinger et. al.
- Can have normal pulses, ABPI but ischemia in a branch of an artery
- More susceptible to heel pressure injury

Angiosome Map of an Ulcer

Limb Salvage Via Interventions

- Access to pedal and tibial vessels of the lower extremities is necessary to perform limb salvage interventions.
- The dorsalis pedis, anterior tibial artery, or posterior tibial artery maybe the only lifeline vessel to the foot.

**Figure 1** ◆ Logistic regression analysis correlating SPP values after EVT with the probability of wound healing

_Utsunomiya M, Nakamura M, Nagashima Y, Sugi K._

_Predictive value of skin perfusion pressure after endovascular therapy for wound healing in critical limb ischemia._

_J Endovasc Ther. 2014 Oct;21(5):662-70_
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Skin Blood Flow Dynamics & its Role in Pressure Ulcers (Injuries)

*Liao, Burns, Jan: 2013*

- Connecting capillaries between the 3 systems
- Capillaries 5-10 µm in diameter surrounded by a basement membrane
- Exchange of nutrients may be regulated by pre-capillary sphincters
- Susceptible to external injury
The **Arterial** & **Venous** Systems
*Connected by Capillaries*

*Koziak 59, Linden et.al 65*

Arterial side
25-32 mm Hg

Venous side
5-10 mm Hg

Interstitial pressure can lead to capillary closure *(e.g. External pressure over Bony prominence)*

**Common Locations of Pressure Injuries**

- Elbow
- Inner knees
- Greater trochanter
- Inner knees
- Shoulder
- Elbow
- Hip
- Lower back and buttocks
- Heel

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Skin Blood Flow Oscillations

Liao, Burns, Jan: 2013

- “Blood flow in micro-vessels is well known for oscillatory as opposed to steady”
- Due to vaso-motion + skin blood flow (SBF) variations
- Laser Doppler flowmetry (LDF) – due to relative motion between the wave source + its observer

Johan Christian Doppler (1803-53)

SBF -6 characteristic frequencies (approx. values)

1. Heart beat – 1 Hz
2. Respiration- 0.3 Hz
3. Myogenic activity of the vascular smooth muscle -0.1= loss with neuropathy (e.g. DM)
4. Neurogenic activity in the vessel wall -0.04 Hz
5. + 6.Vascular endothelial function:
   – Nitric oxide (NO) dependent –0.01
   – NO independent – 0.007

Importance of Skin Blood Flow (SBF)

Liao, Burns, Jan: 2013

Time Domain Analysis of SBF

Implications for Pressure Injury
Importance of Skin Blood Flow (SBF)

*Liao, Burns, Jan: 2013*

**Time Domain Analysis of SBF**

- Reactive hyperemia
  - Peak hyperemia
  - Time to peak
  - Area under the curve
- Longer the arterial occlusion, the greater the hyperemia
- Reproducibility depends on skin site + baseline skin temperature

**Implications for Pressure Injury**

- Tissue ischemia – mechanical loading is a primary factor
- Monitor non-invasively with LDF (Laser Doppler Flow)
- Microvascular impairment/ ischemic stress response may identify persons at risk for PI

**Participants will:**

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Methods:
- 9 power wheelchair users with SCI.
- Sitting for 15 min + Random assigned- tilt in space 3, 1 and 0 min.
  + a second 15 min. seated.

Results: A 3min. duration of wheelchair tilt in space and recline is more effective (p=.017) than the 1 min. and zero durations. (N.S.)

Measuring tissue perfusion during Pressure relief Maneuvers: Insights into preventing Pressure ulcers (PIs) Maksous, Priebe, Bankard et al. 2007

**Objective:** Effect on tissue perfusion – relieving interface pressuring using standard wheelchair push-ups vs. mechanical automated dynamic pressure relief systems

**Methods:** Two-1 hr. sitting protocols
- Normal sitting alternating with offloading positions
- Normal sitting- wheelchair push-up q 20 minutes

**Participants**
- 20 motor complete paraplegia below T4
- 20 with motor tetraplegia
- 20 normal- 10 females, 10 males
Conclusions - Dynamic Wheelchair vs. Wheelchair Push-ups

- Dynamic seating protocol device evaluated in this study had a significant effect on improving tissue perfusion in the buttock area through periodically redistributing the pressure to the thighs.
- Wheelchair push-ups were not sufficient to allow recovery of the buttock tissue.


IPUCc= intelligent PU prevention cushion
Comparison of Skin Perfusion Response with Alternating & Constant Pressures in People with SCI

**Objective:** Two-way factorial design to compare effects of alternating + constant pressures on weight-bearing tissue perfusion in people with SCI, with application for improving alternating pressure support surface usage.

**Subjects:** 28 participants
- 7-cervical injury
- 7-below T6 injury
- 14 normal controls

**Conclusion:** Alternating pressure enhanced the skin perfusion of weight bearing tissues compared with constant pressure in people with SCI (p< 0.01). Normal controls had similar results.

Jan, Brienza, Boninger, Brenes 2010

Blood Perfusion + Transcutaneous O2 in human skin with changes in normal + shear loads- implications for PI's

Manoroma, Baek, Vorro, Sikorskii, Bush 2010

**Background/Methods:**
- 15 subjects
- 7 conditions
- load +/- shear
- measure blood perfusion + transcutaneous oxygen

**Experiments + rest time**
2 min. between
1. Resting arm- fixed wrist/ elbow
2. Normal Load (NL)
3. N.L. + shear
4. N.L. + 1x2 LB Rice Bag (RB)
5. N.L. + 2x2 LB RBs
6. N.L. + 2x2 LB RBs + shear
7. N.L. + max. Shear- lean with entire body on arm

The addition of shear to the loading scenario caused a decrease in perfusion pressure + oxygen to the skin.
Participants have:

- Evaluated and managed- Lower Limb Peripheral Vascular Disease related to Pressure Injury
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- Assessed treatment options to optimize pressure injury associated skin profusion

Parking lot
TABLE 1
Baseline Patient Characteristics

<table>
<thead>
<tr>
<th></th>
<th>All (n=113)</th>
<th>+ Wound Healing (n=89)</th>
<th>− Wound Healing (n=24)</th>
<th>p</th>
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</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>71.5±12.5</td>
<td>72.6±13.2</td>
<td>70.1±9.1</td>
<td>0.036</td>
</tr>
<tr>
<td>Men</td>
<td>84 (74.3%)</td>
<td>62 (69.7%)</td>
<td>22 (91.7%)</td>
<td>0.029</td>
</tr>
<tr>
<td>Hypertension</td>
<td>92 (82.1%)</td>
<td>73 (83.0%)</td>
<td>19 (79.2%)</td>
<td>0.668</td>
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<tr>
<td>Diabetes mellitus</td>
<td>81 (72.3%)</td>
<td>62 (70.5%)</td>
<td>19 (79.2%)</td>
<td>0.398</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>33 (29.5%)</td>
<td>29 (33.0%)</td>
<td>4 (16.7%)</td>
<td>0.121</td>
</tr>
<tr>
<td>Chronic kidney disease</td>
<td>58 (59.9%)</td>
<td>58 (65.9%)</td>
<td>22 (91.7%)</td>
<td>0.013</td>
</tr>
<tr>
<td>Hemodialysis</td>
<td>63 (56.3%)</td>
<td>44 (50.0%)</td>
<td>19 (79.2%)</td>
<td>0.011</td>
</tr>
<tr>
<td>Current smoking</td>
<td>62 (55.9%)</td>
<td>50 (57.5%)</td>
<td>12 (50.0%)</td>
<td>0.514</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>55 (49.1%)</td>
<td>42 (47.7%)</td>
<td>13 (54.2%)</td>
<td>0.576</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>18 (16.1%)</td>
<td>15 (17.0%)</td>
<td>3 (12.5%)</td>
<td>0.591</td>
</tr>
<tr>
<td>Non-ambulatory</td>
<td>49 (43.4%)</td>
<td>36 (40.4%)</td>
<td>13 (54.2%)</td>
<td>0.035</td>
</tr>
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</table>

Medications

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<tr>
<td>Aspirin</td>
<td>89 (78.8%)</td>
<td>71 (79.8%)</td>
<td>18 (75.0%)</td>
<td>0.649</td>
</tr>
<tr>
<td>Clofazol</td>
<td>57 (50.4%)</td>
<td>45 (50.6%)</td>
<td>12 (50.0%)</td>
<td>0.388</td>
</tr>
<tr>
<td>Thienopyridine</td>
<td>42 (37.2%)</td>
<td>31 (34.8%)</td>
<td>184 (45.8%)</td>
<td>0.094</td>
</tr>
<tr>
<td>Warfarin</td>
<td>23 (20.4%)</td>
<td>18 (20.2%)</td>
<td>5 (20.8%)</td>
<td>0.786</td>
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<tr>
<td>Statins</td>
<td>21 (18.6%)</td>
<td>17 (19.1%)</td>
<td>88 (16.7%)</td>
<td>0.383</td>
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<tr>
<td>Total protein, mg/dL</td>
<td>7.0±0.8</td>
<td>7.1±0.8</td>
<td>6.9±0.7</td>
<td>0.073</td>
</tr>
<tr>
<td>Albumin, mg/dL</td>
<td>3.4±0.6</td>
<td>3.5±0.7</td>
<td>31±0.8</td>
<td>0.062</td>
</tr>
<tr>
<td>Hemoglobin, mg/dL</td>
<td>11.2±1.8</td>
<td>11.1±1.8</td>
<td>11.3±1.8</td>
<td>0.224</td>
</tr>
<tr>
<td>HbA1C, %</td>
<td>6.3±1.5</td>
<td>6.4±1.6</td>
<td>6.2±1.3</td>
<td>0.098</td>
</tr>
<tr>
<td>Total cholesterol, mg/dL</td>
<td>163.2±41.1</td>
<td>163.8±41.7</td>
<td>163.9±43.7</td>
<td>0.952</td>
</tr>
<tr>
<td>Triglyceride, mg/dL</td>
<td>117.4±68.3</td>
<td>118.3±73.3</td>
<td>117.5±63.8</td>
<td>0.852</td>
</tr>
<tr>
<td>CRP, mg/dL</td>
<td>2.7±0.4</td>
<td>2.6±0.3</td>
<td>2.9±0.6</td>
<td>0.052</td>
</tr>
</tbody>
</table>

Utsunomiya M, Nakamura M, Nagashima Y, Sugi K.

Fig 3. Comparison of skin perfusion in response to wheelchair tilt-in-space (15°, 25°, 35°) in combination with recline (R: 100°, 120°). During tilted and reclined positions, 4 testing positions showed a significant increase in skin perfusion compared with the upright seated position (P<.05), whereas positions at 15° tilt-in-space and 100° recline and 25° tilt-in-space and 100° recline did not show a significant increase in skin perfusion. Combined with 100° recline, wheelchair tilt-in-space at 35° resulted in a significant increase in skin perfusion compared with wheelchair tilt-in-space at 15° and 25° (P<.05), whereas there was no significant difference between 15° and 25°. Combined with 120° recline, wheelchair tilt-in-space at 35° resulted in a significant increase in skin perfusion compared with 15° tilt-in-space (P<.05). Data shown as mean ± SE. Abbreviation: BPU, blood perfusion unit.

Jan YK, Jones MA, Rabadi MH, Foreman RD, Thiessen A.

Skin Blood Flow Dynamics

Figure 1  Schematic diagram of the architecture of the skin vasculature.


**Figure 2** Skin blood flow (SBF) response in the sacral skin of a healthy subject. (a) Skin blood flow under externally pressure shows a decrease between 10th and 14th min. After the removal of the pressure, skin blood flow shows an increase (reactive hyperemia). (b) SBF response to a rapid local heating to 42 °C shows a biphasic vasodilation. The first peak is mediated by axon reflex and the second plateau is mediated by nitric oxide. (c) SBF response to local cooling to 25 °C. Skin blood flow decreases in response to cooling. PU, perfusion unit.


**Figure 4** An example of wavelet analysis of the LDF blood flow signal shown in Fig. 2a. (a) Instantaneous frequencies corresponding to the local maxima of absolute wavelet coefficients. (b) Wavelet amplitude spectrum.
Qualifying the effects of external shear loads on arterial + venous blood flow: implications for PI’s

Manoroma, Meyer, Wiseman, Bush 2013

Background/ Methods:
• 15 male normal volunteers
• Tested in an MRI:
  – No load
  – Normal load
  – Normal load + shear
• Measured changes in the blood flow of arterial + venous vessels using magnetic resonance angiography phase-contrast imaging