INTRODUCTION
Pressure injuries are local injuries to the skin and/or underlying tissue, often found over bony prominences and caused by exposure to external pressure with or without shear \[1\]. Extended periods of pressure and shear induced ischemia can cause blood vessel damage and tissue necrosis, both of which can lead to pressure injuries \[2\]. Pressure injuries due to prolonged ischemia are especially of concern in patients undergoing long surgeries, where patient repositioning to relieve pressure and promote blood flow cannot be implemented. Jan et al., showed that alternating enhances the skin perfusion on load bearing tissues \[3\]. The intervention was alternating pressure (AP) applied by a single indenter on the sacral bony prominence, however. The impact of a full body AP operating room table overlay on skin perfusion must be quantified.

This study compared the effect on sacral skin blood flow (SBF) over time of a traditional operating room (OR) pad with and without an AP overlay.

METHODS
Protocol
An experimental, crossover research design was implemented using a 2” operating room foam pad (STERIS Corporation, Montgomery, AL) with and without an AP overlay (DabirAIR, DABIR Surfaces, Inc., Chicago, IL). The AP overlay was run on a ten-minute cycle (each zone was inflated for five minutes) and low firmness setting. Healthy participants (n = 20) laid prone on each surface for ten minutes to collect baseline SBF at 10 Hz using LabVIEW (National Instruments, Austin, TX) with a laser Doppler blood flow optic probe (Moor Instruments Inc., Wilmington, DE). Sacral SBF was recorded while the participant laid supine (loaded) for sixty minutes and prone (post-loaded) for ten minutes. Skin temperature was measured with a thermocouple placed (FLUKE Inc., Everett, WA) superior and lateral to the blood flow optic probe.

Data Processing
Raw SBF data was down-sampled to 0.5 Hz using the MATLAB (MathWorks, Natick, MA) command `decimate`, prior to being passed through a 10th order Chebyshev I low-pass filter with cutoff frequency 0.15 Hz \[4\]. SBF data was masked following the filter application to remove movement artifacts noted during the participant trials. Loaded and post-loaded SBF data were normalized to the mean baseline SBF in each test condition.

Data Analysis
Two measures were created to quantify the effect of the AP overlay on SBF. The first variable, \(SBF_R\), described the ratio of the mean SBF over the last 10 minutes of the loaded trial \((SBF_{last 10 \, min})\) to the mean SBF over the first 10 minutes of the loaded trial \((SBF_{first 10 \, min})\) (Equation 1).

\[
SBF_R = \left( \frac{SBF_{last 10 \, min}}{SBF_{first 10 \, min}} \right) \%
\]

The relative effectiveness of the AP overlay, \(\Delta SBF_R\), was the difference between the \(SBF_R\) values in each condition (Equation 2).

\[
\Delta SBF_R = (SBF_R)_{with \, AP \, overlay} - (SBF_R)_{without \, AP \, overlay}
\]
Paired t-tests determined any significant differences between mean participant SBF data. Post-hoc regression analysis examined possible demographic predictors of overlay effectiveness. One participant was found to be non-compliant with the established protocol, thus the data obtained from this participant was excluded from data analysis.

RESULTS
Baseline, loaded and post-loaded SBF were not significantly different between test conditions (Table 2).

Table 2. Mean SBF data of the total population for each test condition. SBF was not significantly different between test conditions for the mean baseline, loaded and post-loaded SBF data.

<table>
<thead>
<tr>
<th></th>
<th>OR Pad Only</th>
<th>OR Pad w/ AP</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline SBF (PU)</td>
<td>12.14 (5.95)</td>
<td>14.77 (7.43)</td>
<td>0.103</td>
</tr>
<tr>
<td>Normalized Loaded SBF</td>
<td>1.04 (0.45)</td>
<td>1.37 (1.08)</td>
<td>0.159</td>
</tr>
<tr>
<td>Normalized Post-loaded SBF</td>
<td>1.37 (0.81)</td>
<td>1.54 (1.89)</td>
<td>0.713</td>
</tr>
</tbody>
</table>

Post-hoc regression analysis showed that participant BMI was a significant predictor of overlay effectiveness. Participant age, gender and mean arterial blood pressure (MAP) were not significant predictors (Table 3).

Table 3. Results from the post-hoc regression analysis. BMI was a significant predictor of overlay effectiveness, while age, gender and MAP were not.

| Effect                  | Estimate | Standard Error | t-Ratio | Prob>|t| |
|-------------------------|----------|----------------|---------|------|
| Intercept               | 0.4073   | 0.3521         | 1.16    | 0.267|
| Age                     | 0.0003   | 0.0021         | 0.15    | 0.884|
| Body Mass Index         | -0.0189  | 0.0085         | -2.21   | 0.044*|
| Gender [Female]         | -0.0563  | 0.0438         | -1.29   | 0.219|
| Mean Arterial Blood Pressure | 0.0003  | 0.0037         | 0.08    | 0.934|

The relationship between participant BMI and overlay effectiveness ($\Delta SBF_{\text{R}}$) was found to be negative. As participant BMI decreased, overlay effectiveness increased ($r = -0.52$).

DISCUSSION
The results suggest that the AP overlay, on low firmness setting and ten-minute cycle speed, was more effective at increasing SBF over time than the OR pad alone in participants with normal BMI ($\text{BMI} < 25$). The results are significant because low BMI/underweight individuals ($\text{BMI} < 19$) are considered an at-risk population for pressure injury development in the ICU [5]. Similar conditions found in an operating room would also pose a significant risk of pressure injury development to these low BMI individuals, therefore validating the effectiveness and purpose of the AP overlay used in the study.

CONCLUSION
Participant BMI is a factor in the response of sacral SBF to AP. Future studies should investigate the effect of alternate cycle speeds and firmness settings on SBF, which may be more effective at increasing SBF over time for participants with higher BMI. Additionally, studies in at-risk populations could be conducted, as the target population for this study was healthy individuals with no history of heart, blood or lung disease.

REFERENCES

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