The Effect of Multiple Layers of Linens on Surface Interface Pressure: Results of a Laboratory Study

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Abstract

Underpads and layers of linens are frequently placed under patients who are incontinent, have other moisture-related issues, and/or are immobile and cannot reposition independently. Many of these patients are also at risk for pressure ulcers and placed on pressure-redistribution surfaces. The purpose of this study was to measure the effects of linens and incontinence pads on interface pressure. Interface sacral pressures were measured (mm Hg) using a mannequin-like pelvic indenter that has pressure transducers integrated into the unit and is covered with a soft flesh-like elastomer. The indenter was loaded to simulate a median-weight male (80 kg/176 lb), and the testing was performed at head-of-bed (HOB) angles of 0˚, 30˚, and 45˚. Two different surfaces, a high performance low-air-loss support (LAL) surface and a standard foam support surface, were used and covered with a fitted sheet (FS) only or a combination of the FS and various incontinence pads and transfer sheets. Linen combinations typically used for relatively immobile patients (n = 4), moisture management (n = 4), and moisture management and immobility (n = 1) were tested, as was the heavy use of linens/pads (nine layers, n = 1). All combinations were tested 10 times at HOB angles of 0˚, 30˚, and 45˚. The highest pressure observed was recorded (peak pressure). Ninety five percent (95%) confidence interval (CI) surrounding the mean of the 10 trials for each combination was calculated using the t-distribution; differences between means for all surface combinations were determined using one-way ANOVA with follow-up Fisher Hayter test. Results indicated that each incontinence pad, transfer sheet, or combination of linens significantly increased the mean peak sacral pressure when compared to a single FS on both the low-air-loss surface and the foam surface, regardless of the head-of-bed angle. The magnitude of peak sacral interface pressure increase for the LAL surface at 30˚ head-of-bed angle was 20% to 64% depending on the linen combination. At 30˚, the foam surface showed increases 6% to 29% (P <0.0001) compared with a FS baseline. If linens were wet, peak interface sacral pressures were equivalent to or less than pressures measured on the same pads when measured dry. The presence of linens on both surface types adversely affected the pressure redistribution capabilities of the surfaces; added layers increased pressure proportionally. The effect on interface pressure from the linen layers was more pronounced on the LAL than the foam surface. The study results illustrate that significant increases in peak interface pressure occur in a laboratory setting when linen layers are added to pressure redistribution surfaces. Results also indicated wetting incontinence pads on a support surface did not significantly increase interface pressure. Although additional preclinical and clinical studies are needed to guide practice, excessive linen usage for patients on therapeutic support surfaces should be discouraged.

Keywords: pressure ulcer, bedding and linens, preclinical study, pressure, support surface

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Potential Conflicts of Interest: The authors are all employees of Hill-Rom, Batesville, IN.
**Literature Review**

Patients are placed on underpads and layers of linens for incontinence, drainage management, ease of transfer, repositioning, and comfort. The strong association between incontinence, immobility, and pressure ulcers also increases the likelihood these layers are frequently used with patients in need of a therapeutic support surface.\(^1\) The effects these layers have on the tissue are an important aspect of patient care. Although large bodies of literature address the effects of pressure on the skin and support surface performance, little has been published examining therapeutic surfaces used in conjunction with linens and underpads, as is the practice in the therapeutic setting.

**Effect of pressure on the skin.** Pressure can contribute to skin breakdown. Prolonged high pressure, particularly over the bony prominences, compresses the tissue and interferes with blood supply and waste removal. Ultimately, tissue damage may occur as a result of the deprivation of nutrients with blood supply and waste removal.\(^2\) Tissue damage may occur as a result of the deprivation of nutrients and accumulation of waste;\(^2,6\) and mechanical damage may be induced by the distortion of the tissue due to shearing effects.\(^4,7\) Therefore, it is essential to understand the effects on pressure of any materials introduced between the support surface and the patient to inform patient care decisions.

**Effect of linens and pads on interface pressure.** Although the vast majority of patients are in contact with some type of bedding materials or incontinence pads, few studies have attempted to assess their effects on the risk of skin breakdown. Fader et al\(^8\) used an instrumented articulated mannequin with soft tissue-like properties in the gluteal and sacral regions to measure the effects of incontinence pads on interface pressure using an Xsensorn pressure-mapping system (Xsensorn Technology Corporation, Calgary, Alberta, Canada). The load was set to 70 kg to simulate a medium-weight patient. Testing was conducted on three different types of foam surfaces: a standard foam product, a surface-cut foam (a product that has a series of shallow slices or grooves in the surface intended to relieve shear), and a viscofoam, which is constructed of foams that rebound more slowly than conventional foams when the pressure is relieved and tend to adjust the compliance properties somewhat to enhance contouring over time. Each of the three surfaces was tested in three combinations: 1) no incontinence pad, 2) wearing a dry pad, and 3) wearing a wet pad. Ten trials were conducted in each condition. The presence of the pad resulted in significant increases in peak pressure of 20% to 25% on all surfaces. On the standard foam, the mean of the 10 measurements of peak interface pressures increased from 70.9 mm Hg to 87.3 mm Hg (mean increase 16.4 mm Hg; 95% confidence interval [CI] 15.1–17.7 mm Hg). On the viscoelastic foam, the mean increased from 71.2 mm Hg to 85.2 mm Hg (mean increase 14.0 mm Hg; 95% CI 9.4–18.6 mm Hg). On the surface-cut viscoelastic foam, peak pressure increased from 67.6 mm Hg to 82.0 mm Hg (mean increase 14.4 mm Hg; 95% CI 11.7–17.8 Hg). \(P\) values were not reported. No significant differences were found between the peak pressures on wet and dry pads. The researchers also noted that peak pressures tended to be associated with folds in the pad, and that peaks could be reduced somewhat by smoothing the pad before placing it under the “body” —ie, the surface of the mannequin.

The National Pressure Ulcer Advisory Panel\(^10\) (NPUAP) recommends use of positioning devices and incontinence pads that are compatible with the support surface and to limit the amount of linen and pads placed on the bed. They also direct clinicians not to leave moving and handling equipment under the individual after use. Both recommendations are presented with strength of evidence of C, indicating they are based on expert opinion with little published support. An analysis\(^11\) of 70,992 patient records from the 2011 International Pressure Ulcer Prevalence Survey™ (IPUP) found the management of nearly 70% of patients in US facilities involves one or more layers of linen between the patient and the support surface; 8.2% of patients with Braden scores in the High (6 to 9) or Very High (10 to 12) risk categories were noted to have five or more layers of linen between the support surface and the skin. These data suggest the importance of understanding the effects of linens on support surface performance.

The purpose of this study was to evaluate the effect on tissue interface pressure of adding incontinence pads and linen layers to a low-air-loss and a foam therapeutic support surface.

**Methods**

**Products.** Two therapeutic support surfaces were studied: 1) Envision® E700 low-air-loss (LAL) support surface (Hill-Rom, Batesville, IN), a dynamic multizoned, high-end therapeutic mattress developed for the prevention and treatment of pressure ulcers in high-risk individuals (Braden scale scores 6 to 12); and 2) NP100 foam support surface...
The surface types selected represent two of the surface categories most frequently used with very high risk patients (Braden scores 6 to 12) based on a study of 97,000-plus patient records included in the 2010 IPUP™ survey. LAL (16.3%) and foam (21.4%) comprised two of the largest surface categories used with this patient population in the hospital setting.

Linen combinations tested were grouped by three common linen functions to address immobility and moisture management as described in informal interviews with WOCN nurses. A knit fitted sheet (FS) (Standard Textile, Cincinnati, OH) served as control and is noted as combination 1. The four immobility combinations include a FS and reusable pad (with or without plastic) that may aid in repositioning or turning patients: combination 2: FS + repositioning sheet (RS) (MIP, Montreal, Quebec); 3: FS + Standard Textile quilted Chux (QC) nonplastic-backed (NP) (Standard Textile, Cincinnati, OH) (QC [ST] NP); 4: FS + Angelica quilted Chux plastic-backed (P) (QC [ANG] P) (Angelica, Alpharetta, GA); and 5: FS + QC [ST] P (Standard Textile, Cincinnati, OH).
The four moisture management combinations comprised a FS and disposable pad (with or without plastic) potentially for incontinence, excessive fluid, and related moisture issues: combination 6: FS + Attends plastic-backed disposable underpad (UP [ATT] DP P) (Domtar Personal Care, Raleigh, NC); 7: FS + Attends paper-backed disposable underpad (UP [ATT] D NP); 8: FS + Medline paper-backed disposable underpad (UP [MED] D NP) (Medline Industries, Mundelein, IL); 9: (FS + Covidien paper-backed disposable underpad (UP [COV] D NP) (Covidien plc, Dublin, Ireland).

The immobility and moisture management is represented by combination 10: FS, RS, UP [ATT] D NP (Domtar Personal Care, Raleigh, NC).

Based on the 2011 IPUP™ survey, which included 65,555 patient records with information on the number of linen layers present, 2% had five or more layers present between the surface and the skin. Therefore, to assess what was believed to be a maximum number of linen layers, one combination had nine layers of linens — combination 11: FS + bath blanket (BB) + flat sheet folded into quarters (4 FS) + quilted Chux with a plastic backing (QC-Plastic) + bath blanket (BB) + QC-Plastic (see Table 1).

**Product testing: interface pressure measurement.** A sensored pelvic indenter (developed by Hill-Rom test laboratories) was used to measure peak interface pressure (IFP) for each surface/linen combination. The indentor was developed from a MRI scan of a 176-lb man and includes 168 pressure sensors 0.5 inches in diameter spaced approximately 1.00 inch apart. The surface of the indenter is covered by a 0.5-inch layer of compliant elastomer. Peak pressure was defined as the single highest sensor value on the indentor. All sensors were calibrated immediately before measurement.

The following procedure was followed:

1. The sensored indentor was attached to the cross-arm of a Materials Testing Machine (MTM) (Instron Model 5566; Instron, Norwood, MA).
2. The Envision™ E700 surface was placed on a VersaCare® frame (Hill-Rom, Batesville IN) and set up according to manufacturer’s instructions for a 50th percentile patient with a weight of 176 lb. The NP100 foam surface was placed on a flat deck frame (Advanta™, Hill-Rom, Batesville, IN).
3. The bed under test was positioned under the MTM such that the pelvic indentor was centered over the central pelvic zone of the mattress.
4. A knit FS was positioned over the support surface and used as a baseline control.
5. The appropriate load for the pelvic region of a 176-lb man with the head of bed (HOB) at 0°, 30°, and 45° was determined by calculating the upper body and pelvis body segment weights in the appropriate posture according to McC Givney et al. The appropriate mean pressures on the underside of the indentor were 9.2 mm Hg, 24.7 mm Hg, and 31.1 mm Hg at 0°, 30°, and 45° HOB angles, respectively. The indentor was lowered and compressed into the center of the mattress until the load measured on the MTM reached the appropriate load calculated above.

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**Table 1. Linen and under pad configurations tested continued**

<table>
<thead>
<tr>
<th>Immobility and moisture management</th>
<th>Disposable pad</th>
<th>Repositioning sheet</th>
<th>Fitted sheet</th>
<th>Bath blanket</th>
<th>Flat sheet folded into quarters</th>
<th>Bath blanket</th>
</tr>
</thead>
<tbody>
<tr>
<td>10: FS, RS, UP [ATT] D NP</td>
<td>Attends Air-Dri Breathables Plus Layered Underpad 30&quot;x36&quot;-86679-23948 (Greenville, NC)</td>
<td>MIP Patient Positioning Device PTD-5 (Montreal, Quebec)</td>
<td>Standard Textile Ultimate Knit Fitted Sheet 60% cotton/40% polyester 0724 3400 (Cincinnati, OH)</td>
<td>Standard Textile Bravado Bath Blanket 50% cotton/50% polyester 81&quot;x108&quot; T-180 (Atlanta, Georgia)</td>
<td>Angelica Reusable Pad (29&quot;x32&quot;) (Alpharetta, GA)</td>
<td>Angelica Reusable Pad (29&quot;x32&quot;) (Alpharetta, GA)</td>
</tr>
<tr>
<td>11: FS, BB, QC-Plastic</td>
<td>Angelica Reusable Pad (29&quot;x32&quot;) (Alpharetta, GA)</td>
<td>Blob Hospital Flat Sheet 50% cotton/50% polyester 81&quot;x108&quot; T-180 (Atlanta, Georgia)</td>
<td>Angelica Reusable Pad (29&quot;x32&quot;) (Alpharetta, GA)</td>
<td>Angelica Reusable Pad (29&quot;x32&quot;) (Alpharetta, GA)</td>
<td>Standard Textile Bravado Bath Blanket 50% cotton/50% polyester 81&quot;x108&quot; T-180 (Atlanta, Georgia)</td>
<td>Standard Textile Bravado Bath Blanket 50% cotton/50% polyester 81&quot;x108&quot; T-180 (Atlanta, Georgia)</td>
</tr>
</tbody>
</table>

Abbreviations: FS = fitted sheet, BB = bath blanket, QC = quilted Chux, UP = underpad, DP = disposable, pad, P = plastic-backed, NP = nonplastic-backed
6. The imposed load was maintained for 60 seconds, at which time the peak IFPs were recorded in order to allow the support surface internal air bladder pressures to reach equilibrium. Of note: Whenever a load is shifted, the support surface bladders adjust internal pressures to minimize interface pressure.

7. The indenter was raised and the surface was allowed to recover for 2 minutes before the next trial. Two minutes of offloading ensured the Envision support surface time to fully adjust its support pressures from the previous load.

8. Steps five through seven were repeated for a total of 10 trials per linen combination.

**Wet testing.** In order to determine if the presence of moisture changed the pressure associated with the use of an underpad, seven linen combinations were evaluated in both the dry and wet conditions. Each underpad was saturated with 500 mL of water, a volume estimated in conversations with clinicians to represent a significant load of urinary incontinence. This volume fully saturated the underpad before the test for the wet condition. Testing then was conducted on the wetted combinations exactly as outlined above for the cases in which the linens were dry. Because the wet testing was focused on the moisture management configurations, linen combinations 2, 5, 10, and 11 were not included in this analysis.

**Data analysis.** Peak sacral pressure was defined as the single highest pressure value in mm Hg among all sensors on the pelvic indentor during each trial. Ten trials were conducted in each combination; the mean peak pressure of these 10 trials was reported as mean peak sacral pressure. Data were stored in Microsoft Excel and analyzed in the Excel Analysis ToolPak. Ninety five percent (95%) CI surrounding the mean of the 10 trials for each combination were calculated using the t-distribution. One-way ANOVA with follow-up Fisher Hayter test (alpha = 0.05) was used to determine differences between means for all surface combinations.

**Results**

**Effect of various linens on IFP performance.**

**LAL surface.** All linen combinations had statistically higher peak IFP when compared to the FS alone, regardless of the HOB angle (P <0.0001). At 30° HOB, the LAL support surface with a single FS had peak sacral pressure of 36.4 mm Hg (see Figure 1 and Table 2). Immobility combinations (combinations 2 through 5) ranged from 43.5 mm Hg (combination 2) to 56.2 mm Hg (combination 3).

**Table 2. Mean peak sacral pressure of LAL support surface at 30° head-of-bed elevation with fitted sheet (FS) alone versus each linen layer combination.**

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Mean peak sacral pressure (mm Hg)</th>
<th>Combination</th>
<th>Mean peak sacral pressure (mm Hg) (P &lt;0.0001 for all values compared to FS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS</td>
<td>36.4</td>
<td>FS, RS</td>
<td>43.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, Std Tex QC NP</td>
<td>56.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, Ang QC NP</td>
<td>43.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, Std Tex QC P</td>
<td>50.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, Atd DP P</td>
<td>44.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, Atd DP NP</td>
<td>47.9</td>
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<td></td>
<td></td>
<td>FS, Med DP NP</td>
<td>46.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, Cov DP NP</td>
<td>47.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, RS, Atd DP NP</td>
<td>43.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, BB, FS, QC, BB, QC</td>
<td>55.7</td>
</tr>
</tbody>
</table>

**Table 3. Mean peak sacral pressure of foam support surface at 30° head-of-bed elevation with fitted sheet alone versus each linen layer combination.**

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Mean peak sacral pressure (mm Hg)</th>
<th>Configuration</th>
<th>Mean peak sacral pressure (mm Hg) (P &lt;0.0001 for all values when compared to FS alone)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS</td>
<td>46.2</td>
<td>FS, RS</td>
<td>52.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, Std Tex QC NP</td>
<td>58.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, Ang QC NP</td>
<td>51.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, Std Tex QC P</td>
<td>57.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, Atd DP P</td>
<td>48.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, Atd DP NP</td>
<td>54.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, Med DP NP</td>
<td>52.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, Cov DP NP</td>
<td>56.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, RS, Atd DP NP</td>
<td>52.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FS, BB, FS, QC, BB, QC</td>
<td>60.8</td>
</tr>
</tbody>
</table>
The four incontinence combinations (combinations 6 through 10) also had statistically higher peak IFP ($P < 0.001$) at $30°$ HOB, ranging from $44$ mm Hg (combination 6) to $47.9$ mm Hg (combinations 7 and 9) when compared to the single FS at $36.4$ mm Hg ($P < 0.0001$). Peak sacral pressure using the immobility and moisture management combinations was $43.4$ mm Hg ($P < 0.0001$), and the nine-layer linen had a mean peak sacral pressure of $55.7$ mm Hg ($P < 0.0001$) (see Figure 1). Peak pressures increase with increasing layers of linens (see Figure 2).

For the moisture management group, the disposable pads without plastic produced statistically higher peak sacral pressures when compared to the disposable pad with plastic on the LAL surface at $30°$ HOB. The pads without plastic backing had IFPs 7% to 12% higher than those with plastic.

**Foam surface.** As with the LAL surface, each additional layer or combination of layers caused a significant increase in peak sacral pressure at all HOB elevations as compared to the single FS (see Figure 3 and Figure 4).

With the HOB angle at $30°$ on the foam surface, all 10 linen combinations resulted in highly significant increases in peak sacral pressure compared to the FS. Using the FS alone, mean peak sacral pressure was $46.2$ mm Hg; immobility combinations ranged from $52.2$ mm Hg (combination 2) to $58.1$ mm Hg (combination 3) ($P < 0.0001$) (see Table 4). Peak pressures increase with increasing layers of linens (see Figure 2).

Similarly, the moisture management combinations had significantly higher peak IFPs, ranging from $48.8$ mm Hg (combination 6) to $56.7$ mm Hg (combination 9) ($P < 0.0001$). Peak sacral pressure using the combined immobility and moisture management combinations was $52.3$ mm Hg ($P < 0.0001$). The nine-layer linen combination had a peak sacral pressure of $60.8$ mm Hg, which was 31% higher than the $46.2$ mm Hg peak IFP of the single-linen layer ($P < 0.0001$).

**Wet linens and IFP performance.** When underpads were saturated with $500$ mL of water (a volume estimated to represent a significant load of urinary incontinence per conversations with clinicians), the peak IFPs for the wet pads were either equivalent to or lower than those measured when the pads were dry with the exception of combination 7 at $0°$ HOB (see Figure 5).

**Discussion**

The results of this study indicate the presence of linens or incontinence products between a support surface and the body can substantially reduce the surface’s ability to redistribute pressure. Unfortunately, patients who are at risk or who already have pressure ulcers, are also frequently incontinent and immobile. This study suggests that over-utilization of linens and the use of some incontinence pads intended to protect against moisture-associated damage may actually be an additional risk factor for pressure ulcer development.

Every combination of linens and/or incontinence pads used in this study led to significant increases in peak sacral IFP compared to the FS used alone. For any given incontinence pad or transfer sheet, the magnitude of the increase was $12.9$ mm Hg ($P < 0.001$) at $0°$ HOB, $24.0$ mm Hg ($P < 0.001$) at $45°$ HOB over the FS and LAL surface, and $12.7$ mm Hg ($P < 0.001$) at $0°$ HOB to $17.8$ mm Hg ($P < 0.001$) at $45°$ HOB over the FS and foam surface. The magnitude of this increase was $17%$ to $56%$ on the LAL surface and $6%$ to $44%$ on the foam surface. The combination with the greatest number of linen layers (nine layers in combination 9) had the highest interface pressure on both surfaces.

These findings are consistent with the preclinical study findings of Fader et al., who observed use of an incontinence pad increased pressures by 20% to 25% on a standard hospital mattress and two pressure-reducing therapeutic foam surfaces. It is interesting to note that when a disposable, paper-backed pad was placed on top of the LAL surface and FS, the peak sacral pressure increased from $36$ mm Hg to $46$ mm Hg at $30°$ HOB, which made this high-performing therapeutic surface indistinguishable from the simple foam product combined with a FS that had peak IFPs of $46.2$ mm Hg. Clinicians should be aware of the therapeutic reduction associated with additional linen layers, minimize linen layers to what is absolutely necessary, and use better performing pads.

An additional observation was that IFPs were proportionately more affected by the presence of linens on the LAL than the foam surface. From a percentage standpoint, the presence of linens on the LAL surface increased peak sacral IFP to a greater extent than on the foam surface (combination 2: $19.5%$ on the LAL versus $13.0%$ on foam; combination 3: $54.4%$ on the LAL versus $28.8%$ on foam; combination 4: $19.8%$ on the LAL versus $10.8%$ on foam; combination 5: $63.5%$ on the LAL versus $23.4%$ on foam; combination 6: $20.9%$ on the LAL versus $5.6%$ on foam; combination 7: $31.6%$ on the LAL versus $18.2%$ on foam; combination 8: $24.6%$ on the LAL versus $18.2%$ on foam; combination 9: $31.6%$ on the LAL versus $22.7%$ on foam; combination 10: $19.2%$ on the LAL versus $13.2%$ on foam; combination 11:

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**Table 4. Percentage increase in peak sacral interface pressure versus fitted sheet alone for foam versus low air-loss (LAL)**

<table>
<thead>
<tr>
<th>Combination</th>
<th>Low air-loss (LAL)</th>
<th>Foam</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>19.5%</td>
<td>13.5%</td>
</tr>
<tr>
<td>3</td>
<td>54.4%</td>
<td>28.8%</td>
</tr>
<tr>
<td>4</td>
<td>19.8%</td>
<td>10.8%</td>
</tr>
<tr>
<td>5</td>
<td>63.5%</td>
<td>23.4%</td>
</tr>
<tr>
<td>6</td>
<td>20.9%</td>
<td>5.6%</td>
</tr>
<tr>
<td>7</td>
<td>31.6%</td>
<td>18.2%</td>
</tr>
<tr>
<td>8</td>
<td>24.6%</td>
<td>18.2%</td>
</tr>
<tr>
<td>9</td>
<td>31.6%</td>
<td>22.7%</td>
</tr>
<tr>
<td>10</td>
<td>19.2%</td>
<td>13.2%</td>
</tr>
<tr>
<td>11</td>
<td>53.0%</td>
<td>31.6%</td>
</tr>
</tbody>
</table>
53.0% on the LAL versus 31.6% on foam). This is an important consideration because more compliant highly pressure-distributing surfaces typically selected for at-risk patients may be disproportionately affected by the presence of multiple layers of linens.

Wetting the incontinence pads with 500 mL of water did not increase the peak sacral IFP over the dry pad with the exception of combination 7 at 0° HOB elevation. Fader et al⁹ also found that wetting the incontinence pad did not increase peak pressures. It should be noted that this result does not diminish the importance of frequent pad changes, because moisture is known to adversely affect skin integrity independent of IFP.¹⁶ Fader et al¹⁷ examined pad-changing frequency on the rates of pressure ulcers among 81 residential care subjects. The incidence of partial-thickness pressure ulcers was significantly higher in the group managed by less frequent
changes, suggesting the damage was apparently due more to
the effects of prolonged exposure to moisture and/or waste
products than increased pressure.

Limitations
The potential combinations, surface products, and lin-
ens are extensive; the present study used only a small por-
tion of the products available on the market. Additionally,
the effects of individual products were not compared for
their effects on IFP. Finally, this study did not include actual
human subjects and, in the clinical setting, pressure is not
constant, as patient movements are likely to result in dif-
fences in linen shapes and wrinkle patterns. This, in turn,
also may affect pressure-redistribution capabilities. There-
fore, the results of this study cannot be used to identify spe-
cific sheets or incontinence pads that could be considered
to have more favorable effects on IFP. More research on the
effects of specific linens and linen configurations on both
IFP and microclimate management performance is needed.
to assist caregivers in making informed choices when managing high-risk patients and those who have pressure ulcers.

Conclusion
Pressure is a critical factor that can contribute to skin breakdown. The results of this laboratory study showed the presence of linens on the bed surface generally adversely affect the pressure-redistribution capabilities of the surface on which they are placed. Results suggest caregivers should limit the presence of linens on the surface to products that are absolutely necessary. This is particularly true when using high-performance therapeutic surfaces with high pressure-redistributing capabilities, as exemplified by the LAL surface used in this study. Key findings show the presence of a linen or incontinence pad on top of a FS can increase peak sacral IFP by 9% to 56%. Use of a relatively thin, breathable, disposable incontinence pad increased the IFP on dynamic, multizoned air product performance to the level of a passive foam surface. Although this finding is specific to the two surface types tested here, this observation is notable and should be tested further. Heavily wetting the incontinence pad did not significantly increase the IFP over what was measured using the dry pads, with the exception of one linen combination at 0˚ HOB.

In general, “less is best.” Adding multiple layers to a surface tended to increase the peak pressure more than simply adding a transfer sheet or an incontinence pad. The type of material used in the linens or underpad also may play a role in the increase in pressure, because they may compromise the support surface’s ability to redistribute pressure.

Acknowledgment
The authors acknowledge the contribution of Frank Sau- ser, MS, who developed the instrumented pelvic indentor and used it to collect the interface pressure data for this study.

Figure 5. This figure compares dry linens to the corresponding wet linen layers shown on the right of each set of columns. Sacral pressure comparisons are made using mean and standard error (N=10 trails) for three different head-of-bed elevations. Horizontal dashed lines represents the top end of 95% confidence interval for each head-of-bed elevation.
Linen Layers and Interface Pressure

References

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