ORIGINAL RESEARCH

Effects of turning on skin-bed interface pressures in healthy adults

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Accepted for publication 28 January 2010

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Abstract

Title. Effects of turning on skin-bed interface pressures in healthy adults.

Aim. This paper is a report of a study of the effects of lateral turning on skin-bed interface pressures in the sacral, trochanteric and buttock regions, and its effectiveness in unloading at-risk tissue.

Background. Minimizing skin-support surface interface pressure is important in pressure ulcer prevention, but the effect of standard patient repositioning on skin interface pressure has not been objectively established.

Methods. Data were collected from 15 healthy adults from a university-affiliated hospital. Mapped 24-inch × 24-inch (2304 half-inch sensors) interface pressure profiles were obtained in the supine position, followed by lateral turning with pillow or wedge support and subsequent head-of-bed elevation to 30°.

Results. Raising the head-of-bed to 30° in the lateral position statistically significantly increased peak interface pressures and total area ≥32 mmHg. Comparing areas ≥32 mmHg from all positions, 93% of participants had skin areas with interface pressures ≥32 mmHg throughout all positions (60 ± 54 cm²), termed ‘triple jeopardy areas’. The triple jeopardy area increased statistically significantly with wedges as compared to pillows (153 ± 99 cm² vs. 48 ± 47 cm², P < 0.05).

Conclusion. Standard turning by experienced intensive care unit nurses does not reliably unload all areas of high skin-bed interface pressures. These areas remain at risk for skin breakdown, and help to explain why pressure ulcers occur despite the implementation of standard preventive measures. Support materials for maintaining lateral turned positions can also influence tissue unloading and triple jeopardy areas.

Keywords: interface pressure, lateral turning, nursing, patient positioning, pressure ulcers
Introduction

Pressure ulcers pose a significant problem for patients and healthcare providers, with a prevalence of up to 38% in some settings (Weststrate & Bruining 1996, Lyder 2003, Haalboom 2005, Reddy et al. 2006). This increases cost, length of stay, morbidity and mortality. Pressure ulcers, considered preventable, have become a liability for hospitals and caregivers (Agostini et al. 2001, Clark & Price 2004). It has been estimated that US$11 billion are spent on pressure ulcer treatment each year in the United States of America (USA) (Reddy et al. 2006), with similar high treatment costs seen around the globe (Clark & Price 2004, Haalboom 2005; Milne & Pagnamenta 2008). The cost of managing one full-thickness ulcer can be as much as US$70,000 (Reddy et al. 2006). Furthermore, the Centers for Medicare and Medicaid Services (CMS) use pressure ulcers as a quality measure, and recently determined that they will no longer pay the additional expense of caring for hospital-acquired pressure ulcers (Medicare Program 2007). To address this change in policy, the Wound, Ostomy and Continence Nurses Society (WOCN 2009) has introduced a position paper that refutes the assumption that all pressure ulcers are avoidable.

Pressure ulcers result from increased pressure on the skin and subcutaneous tissues, which compromises blood flow and renders the tissues ischaemic (Colin et al. 1996). Oxygen delivery declines when tissue pressure exceeds the capillary-closing pressure. Estimates of capillary pressures usually range from 10 to 30 mmHg (Guyton & Hall 2000), but may be lower for individuals in poor health (Dealey 1995). Thus, when the interface pressure between the skin and supporting surface exceeds capillary closing pressure, commonly assumed to be at 32 mmHg (Landis 1930, Bouten et al. 2003, Swain 2005), tissue hypoperfusion occurs (Reddy 1990, Rithalia & Gonsalkorale 1998, Gebhardt 2005). The longer that pressure exceeds the local capillary closing pressure in one area, the more likely tissue injury and a subsequent pressure ulcer will result.

Turning patients regularly to reduce interface pressures and prevent pressure ulcers is a standard of care (Colin et al. 1996, Rithalia & Gonsalkorale 1998, Lyder 2003, Bergstrom 2005, Defloor et al. 2005, Dini et al. 2006, Vanderwee et al. 2007). Several studies in which turning was used as a chief intervention strategy have failed to reduce the incidence of pressure ulcers (Hobbs 2004, Defloor et al. 2005, Vanderwee et al. 2007). Although maintaining the skin-support surface interface pressure below a capillary closing pressure of 32 mmHg would be expected to reduce pressure ulcer risk, the effectiveness of turning patients to accomplish this goal remains to be established.

Background

Recent researchers have attempted to determine the effect of turning frequency on the incidence of pressure ulcers. Defloor et al. (2005) compared frequent turning of older nursing home residents (Braden score < 17 or Norton score < 12) on a standard mattress with less frequent turning on a pressure-reducing mattress. There was no difference in the incidence of grade I pressure ulcers (pressure ulcer stages can be found at the NPUAP website: http://www.npuap.org/pr2.htm) (NPUAP 2007). However, results from Defloor et al. demonstrated a statistically significantly lower incidence of grade II-IV pressure ulcers when a patient lying on a pressure-reducing mattress was turned every 4 hours compared to turning every 2 or 3 hours on a standard mattress.

Vanderwee et al. (2007) studied an experimental turning routine on older nursing home patients by alternating 2-hour lateral positions with a 4-hour supine position in comparison to a routine of repositioning every 4 hours. The experimental group demonstrated a lower, but not statistically significant, incidence of grade II-IV pressure ulcers, suggesting that more frequent turning does not necessarily lower pressure ulcer incidence. Hobbs (2004) also demonstrated this finding upon implementing a ‘turn-team’ in a hospital for older patients. Results showed no reduction in pressure ulcer incidence despite a decrease in average length of stay. It remains unclear which turning protocols are best, or even if the act of turning is, in fact, substantially protective against pressure ulcer development. Given the limited demonstrated benefits of turning in reducing the incidence of pressure ulcers, we sought to determine how effective turning is at unloading at-risk tissue.

The study

Aim

The aim of the study was to examine the effects of lateral turning on skin-bed interface pressures in the sacral, trochanteric and buttock regions, and its effectiveness in unloading at-risk tissue.

Design

This was a descriptive, observational study. Data were collected over an 18-month period spanning 2005–2007.

Materials

Interface pressure measurement profiles were obtained from a 24-inch × 24-inch square sensor array pad and
pressure-mapping system (Xsensor, Calgary, Canada). The array pad, consisting of 48 x 48 (2304) independent half-inch sensors, is thin and flexible, and uses proprietary capacitive technology to discretely measure the interface pressures applied to the pad. An interface box relays the individual pressure information from each sensor to a computer for real-time visualization and recording. Calibration is performed by placing the sensor array pad between air bladders inflated to specific pressures. Accuracy is ±10%. The device was calibrated to measure pressures from 0 to 200 mmHg.

A modern intensive care unit (ICU) bed was the setting for all measurements (Total Care, Hill-ROM, Batesville, IN, USA). The mattress uses low air loss technology that provides airflow beneath the patient and uses proprietary weight-based pressure settings for different mattress zones. The head of bed (HOB) was adjusted with the side rail controls, and the angle of HOB elevation was measured with the bed’s built-in ball bearing display located in the side rail of the bed. A CXTA01 tilt sensor (Crossbow Technology Inc., San Jose, CA, USA) was used to confirm the HOB angles by also taking measurements at the participants’ sternums. The tilt sensor was also used to measure the angle of the lateral turn. The lateral turn angle was measured in the pelvic region by placing the sensor array pad between air bladders inflated to specific pressures. Accuracy is ±10%. The device was calibrated to measure pressures from 0 to 200 mmHg.

Participants
Participants were healthcare workers from a university hospital. A total of 14 men and one woman gave informed consent and participated in the study, with pillows as support. The participants were healthy adults from 23 to 54 years of age (36.7 ± 7.3). Their heights ranged from 1.70 to 1.85 m (1.8 ± 0.04 m), and they weighed between 65.8 and 122.5 kg (87.2 ± 17.7 kg). The resulting body mass indices (BMIs) ranged from 20.3 to 38.7 (26.8 ± 5.5). Eight of the 15 participants underwent the experimental turning protocol a second time, with wedges, to determine any differences between the two supporting surfaces.

Data analysis
Matlab (Mathworks, Natick, MA, USA) and Excel (Microsoft, Redmond, WA, USA) were used to plot, image, align, analyse and compare the interface pressure profile data. Each profile provided the interface pressure (mmHg) at each of the 2304 discrete sensors. The interface pressure profiles from each position consisted of ten successive measurement readings. The average of these profile measurements was used for analysis of the corresponding position. The reliability of the averaged profiles is evident in that 99.1% of the individual sensors had a standard deviation of less than 2 mmHg across all participants and positions. The maximal pressures were determined, and the at-risk area that was subjected to various pressure thresholds was calculated. The supine images obtained before lateral turning were aligned using 2-D cross-correlation to determine how the turning altered interface pressures. spss 15.0 (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. Repeated measures analysis of variance was used to determine any statistical differences in the peak interface pressures and at-risk areas between the successive turned positions for each side. Paired t-tests were used to compare pillows to wedges at the various positions. A P < 0.05 was considered statistically significant.
Results

Interface pressures and at-risk areas

Peak peri-sacral area interface pressures were not significantly affected by lateral turning, but did demonstrate a statistically significant increase upon elevating the HOB to 30° (Figure 1). We defined ‘at-risk areas’ as skin surface over which an interface pressure greater than 32 mmHg was observed. At-risk areas between the supine and laterally turned (left or right) positions were not statistically different. However, the at-risk areas in the elevated turned positions were statistically greater than their corresponding supine and laterally turned positions (Figure 2). It was readily visible that, despite turning, areas intended to be unloaded from pressure still experienced significant levels of interface pressure, and remained at risk (Figure 3).

Triple jeopardy at-risk areas

Every position exhibited specific at-risk areas of skin that overlapped with all other positions in all but one participant (14 out of 15). We have termed the tissue area at risk in all positions the ‘triple jeopardy area’ because the skin is at risk in all three positions: supine, left-turned, and right-turned. In this case, the pressure is never relieved via turning as intended; see Figures 4 and 5 for examples. The mean triple jeopardy area was 60 ± 54 cm², with a range of 0–198 cm².

Pillows vs. wedges

Eight participants were studied with sequential turning support by both foam pillows and wedges. In this group, there was no statistically significant difference in peak interface pressures at any of the positions between the two techniques. However, the at-risk areas were statistically larger with wedges than with pillows at the lateral left and elevated left positions.

The triple jeopardy area increased dramatically using wedges (153 ± 99 cm², range: 29–335 cm²) when compared to pillows (48 ± 47 cm², range: 0–150 cm²), and was statistically significant. Seven of eight participants demonstrated an increase in the triple jeopardy area using wedges compared to their triple jeopardy area measurement with pillows.

The turn angle measurements for the pillow and wedge techniques are listed in Table 1. The turn angles using either technique (turned left and right) were: reference supine angles ranged from 0 to 2°; lateral turn angles ranged from 31 to 40°; and head-elevated turn angles ranged from 28 to 33°. Statistically significant differences in turn angles were demonstrated between the pillows and wedges only in the lateral right and elevated right positions.
Effect of body habitus

Because our participants represented various body types, the data were analysed to see if height, weight or BMI affected the results. No trend emerged upon analysing peak interface pressures as height, weight or BMI increased. However, for at-risk areas, an increasing trend began to emerge as weight and BMI increased, but not height. As for triple jeopardy areas, again an increasing trend began to emerge as weight and BMI increased, but not height. When viewing the interface pressure profiles, there did not appear to be any noticeable differences between varying heights, weights or BMIs apart from the relative size of the participant.

Discussion

Study limitations

Our study has some limitations. First, tissue interface pressures do not directly assess internal tissue and capillary pressures (Swain 2005). However, interface pressure mapping is currently the best available method to measure pressures exerted on the skin non-invasively. Although not internal, these interface pressure measurements provide a good representation of the pressures exerted on the tissue just below the surface of the skin. Qualitatively, it should be recognized that increasing or decreasing interface pressures...
will consequently increase or decrease the resulting internal pressures experienced by the underlying tissues. Second, we studied healthy adults and not patients. Healthy participants are likely to have better gluteal muscle tone and bulk than typical at-risk patients. Better muscle tone and bulk can elevate the sacrum above the support surface and aid in pressure relief (Maklebust et al. 1986), and greater bulk can redistribute pressure within tissues from surface pressure points. Consequently, even higher peak pressures could be expected in at-risk patients (Sideranko et al. 1992). Third, we only measured participants on a single brand of a modern ICU bed, but we expect that the results would be qualitatively similar regardless of type of mattress. The interface pressures at the various positions are expected to be different on different beds/mattresses, but the relative trends of increased peak pressures, at-risk areas, and triple jeopardy areas should hold true. Finally, the traditional threshold of 32 mmHg for tissue damage has been disputed (Landis 1930, Swain 2005). Interface pressures greater than the capillary closing pressure can be tolerated for some time before ischaemia results (Bader 1990). However, we expect that avoiding pressures that exceed capillary closing pressure should substantially reduce the risk for tissue ischaemia and resultant pressure ulcers.

Relief of pressure

Regular turning of patients is routinely used ostensibly to decrease the risk of pressure ulcers, and is considered a standard of care. As shown by our results, standard turning by an experienced ICU nurse does not reliably relieve elevated skin-bed interface pressures as intended. In our sample, 14 of 15 participants demonstrated a significant triple jeopardy area, suggesting that the current turning process is not reliably effective at unloading skin subjected to pressures believed to put it at risk for pressure ulcer formation. Essentially, there were areas of skin, predominantly near or around the sacrum, that were always at risk and were not relieved by turning in all but one of our participants. This observation lends support to the position paper by the WOCN Society (2009) that even excellent multidisciplinary care, as currently prescribed, may not prevent the development or worsening of pressure ulcers.

Table 1 Mean turn angles and standard deviations comparing the pillow and wedge techniques

<table>
<thead>
<tr>
<th>Position</th>
<th>Turn angle (°)</th>
<th>SD (°)</th>
<th>Turn angle (°)</th>
<th>SD (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillows</td>
<td></td>
<td></td>
<td>Wedges</td>
<td></td>
</tr>
<tr>
<td>Supine</td>
<td>1-1</td>
<td>1-8</td>
<td>0-7</td>
<td>2-0</td>
</tr>
<tr>
<td>Lateral left</td>
<td>34-3</td>
<td>8-4</td>
<td>35-0</td>
<td>5-4</td>
</tr>
<tr>
<td>Elevated left</td>
<td>30-7</td>
<td>7-6</td>
<td>30-7</td>
<td>5-8</td>
</tr>
<tr>
<td>Supine</td>
<td>0-8</td>
<td>2-7</td>
<td>1-9</td>
<td>1-2</td>
</tr>
<tr>
<td>Lateral right*</td>
<td>33-3</td>
<td>6-2</td>
<td>40-2</td>
<td>7-8</td>
</tr>
<tr>
<td>Elevated right*</td>
<td>28-8</td>
<td>7-9</td>
<td>33-3</td>
<td>7-2</td>
</tr>
</tbody>
</table>

*P < 0.05 for turn angle differences between pillows and wedges.
the HOB is an important component of modern ‘best practice’ care in mechanically ventilated patients, as it has been demonstrated to reduce the risk of ventilator associated pneumonia (Drakulovic et al. 1999). However, as a consequence of increased HOB elevation, increased skin-bed interface pressures result. Although, intuitively, HOB elevation should increase peri-sacral area interface pressure, it does not necessarily follow that the at-risk skin surface area also increases. Both of these findings were identified for the supine position at various HOB elevations (Peterson et al. 2008). Because our study shows that elevating the HOB increases the maximum pressures experienced on the perisacral and trochanteric skin regions, and also increases the total area at risk for developing a pressure ulcer, the standard practice of elevating the HOB may increase the risk of skin breakdown.

We also measured larger at-risk areas when turning with wedges for support compared to pillows, dependent on the magnitude of the turn. The significantly larger turn angles observed for the lateral right and elevated right positions (Table 1) resulted in relatively more relieved tissue and less at-risk area for right lateral turns than for the left. The difference in turn angles resulted from variations in nursing technique. For either pillows or wedges, the turn angles achieved were somewhat less in the elevated (left and right) positions than the lateral (left and right) positions because of the participants’ natural tendency to roll more supine upon raising the HOB. In addition to the increased at-risk areas using wedges, the triple jeopardy at-risk area increased more than three-fold.

The limited reports of the effects of lateral turning on skin-support surface interface pressures do not describe monitoring the at-risk areas subjected to various pressure thresholds. In lateral turning studies, Maklebust et al. and Defloor both report interface pressure results (Table 2). Maklebust et al. (1986) measured tissue interface pressures with discrete electropneumatic sensors over the sacrum of participants on a hospital mattress with three different coverings in the supine position. Defloor (2000) used pressure mapping to measure interface pressures in various positions on two mattresses. His results showed that, on a standard hospital mattress, a 30° lateral position had significantly lower peak pressures than 90° lateral-lying positions. On a pressure-reducing mattress, the 30° lateral position was only significantly lower than the 90° lateral position while lying on the shoulder.

A comparison of our results to these studies can be seen in Table 2. The differences in interface pressure magnitude between studies can partially be attributed to different beds/mattresses, participants, and pressure measurement instruments. However, our results suggest that interface pressures are actually considerably higher than once believed. Differences between our results and those of Defloor for corresponding positions can potentially be attributed to our instrumentation having much greater resolution in the peri-sacral area. Defloor used a measurement device that covered the entire mattress with 684 sensors, whereas we used a device with 2304 sensors placed under the sacrum. With lower resolutions, high localized interface pressures spread over a larger sensor area result in lower observed pressure. Higher resolution instrumentation allows for more precise measurement of interface pressures and changes that occur during lateral turning. The pressure mapping technique we employed can measure interface pressures and areas occurring anywhere over the weight-supporting tissue, which cannot be done by a discrete sensor.

We made attempts to measure various body types (weights and BMIs) to determine if tissue is unloaded differently due to these factors. The results show that, regardless of body type, triple jeopardy areas were still observed. The emerging trends can only suggest, due to the small sample size, that larger participants (weight and BMI) will have greater at-risk areas and triple jeopardy areas, which would be expected simply because of their larger skin surface areas.

### Table 2 Comparison of maximum interface pressure measurements (mmHg) from three studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Patient position</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Supine</td>
<td></td>
<td>Laterally turned</td>
<td>Turned with HOB elevation</td>
</tr>
<tr>
<td>Current study (n = 15)</td>
<td>68.6 ± 19.5 (L), 65.8 ± 11.7 (R)</td>
<td>69.2 ± 12.8 (L), 64.8 ± 9.1 (R)</td>
<td>84.5 ± 17.5 (L), 80.4 ± 11.4 (R)</td>
<td></td>
</tr>
<tr>
<td>Maklebust et al. (1986)</td>
<td>12–19 (1)</td>
<td>39.5 ± 7.0 (2), 27.7 ± 4.1 (3)</td>
<td>51.4 ± 15.4 (2), 38.6 ± 8.5 (3)</td>
<td></td>
</tr>
<tr>
<td>Defloor (2000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

L, prior to, or turned to left side; R, prior to, or turned to right side (both directions on a modern ICU bed); HOB, head of bed; 1, standard mattress or covering; 2, standard mattress; 3, polyethylene-urethane mattress.
Conclusion

Standard turning by experienced ICU nurses does not reliably unload all areas of high skin-bed interface pressures. These areas remain at risk for skin breakdown, and may explain why pressure ulcers occur despite the implementation of standard preventive measures. Additionally, support materials for maintaining lateral turned positions can influence tissue unloading and triple jeopardy areas, and need to be further evaluated to improve care.

Further study is needed to evaluate actual patients at risk of developing pressure ulcers and to establish methods to achieve optimum positioning to reduce – and even eliminate – the triple jeopardy areas, peak interface pressures and overall at-risk areas. In addition, clinical studies are needed to determine whether patients with large areas of triple jeopardy are, in fact, more likely to develop a pressure ulcer, or if they develop more serious pressure ulcers.

Acknowledgement

Kevin P. McCutcheon, CCN, is gratefully acknowledged for his assistance in data collection.

Funding

The support for this work was provided by the Department of Anesthesiology, University of Florida College of Medicine, and the J. Crayton Pruitt Family Department of Biomedical Engineering, University of Florida College of Engineering, and Shands Hospital at the University of Florida, Gainesville, Florida.

Conflict of interest

No conflict of interest has been declared by the authors.

Author contributions

MP, WS, JV, NG and LC were responsible for the study conception and design. MP, WS and LC performed the data collection. MP performed the data analysis. MP, WS, JV, NG and LC were responsible for the drafting of the manuscript. MP, WS, JV, NG and LC made critical revisions to the paper for important intellectual content.

References


prevention of pressure ulcers using transcutaneous oxygen and carbon dioxide pressures. *Advanced Wound Care* 9, 35-38.


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