Optimizing Seating in the Intensive Care Unit for Patients With Impaired Mobility

By Teresa Ann Williams, RN, PhD, M Hlth Sci, Grad Dip Clin Epi, Gavin D. Leslie, RN, PhD, FRCNA, Robert Bingham, M Biomed, MIEAust, and Linda Brearley, RN, B Ec

Background Having intensive care patients sit out of bed improves their respiration and psyche and reduces complications of immobilization.
Objectives To compare seating interface pressures to determine a preferred seating surface for patients sitting out of bed.
Method The study was conducted in 2 phases among intensive care patients with impaired mobility who could sit out of bed. Pressure mapping was used to test seating surfaces in a nonrandomized crossover design. In phase 1, three surfaces were compared: (1) regular chair (TotaLift-II), (2) regular chair with gel overlay, and (3) alternative chair (Hausted APC). A new surface, informed from phase 1, was designed and compared with the regular chair surface in phase 2. The number of cells recording pressures of 200 mm Hg or higher (excessive pressure) for 30 minutes was compared between surfaces.
Results In phase 1, the alternative chair had fewer excessive pressures than did the regular chair in 67% of seating episodes among 18 patients ($P < .001$), but the alternative chair lacked practical utility. In phase 2, the new seating surface was compared with the regular surface using the regular chair frame for 20 patients. Among patients with excessive pressures, most (93%) had fewer excessive pressures recorded on the new surface than on the regular surface ($P < .001$).
Conclusion Results from this study provided important data for development of a new seating surface for intensive care patients sitting out of bed. The new surface promotes patients' comfort and probably reduces risk of pressure ulcers. (*American Journal of Critical Care.* 2011;20:e19-e27)

doi: 10.4037/ajcc2011239

Sitting out of bed offers numerous physiological and psychological benefits for critically ill patients, and recent improvements in ventilation modes, miniaturization of technology, and sedative agents have facilitated these benefits. The increased comfort for patients and the minimization of the risk for pressure ulcers also are important. Critically ill patients are at particular risk for development of pressure ulcers.[1] Risk factors include unrelieved pressure, friction, shear, decreased mobility, edema, nutrition, moisture, temperature, and treatments received (eg, vasopressors).[1,2] Patients who are sitting out of bed in the intensive care unit (ICU) often have decreased consciousness, impaired mobility, and inability to assist in their own repositioning. Prolonged sitting or inadequate support surfaces of chairs should be avoided whenever possible.[3] Ideally, the contact area should be maximized in order to distribute the pressure at the seat-buttock interface.

Relief of pressure by regular repositioning and the use of alternating air flow mattresses is a major consideration for ICU patients while in bed, but less emphasis has been placed on measures to promote comfort and reduce pressure when patients are sitting out of bed.

For patients who are sitting out of bed, the pressure between the patient's body and the seating surface (ie, the seating interface pressure) is particularly relevant.[4] Seating interface pressure can be estimated by using pressure-mapping techniques. Pressure mapping is a visual tool that maps the distribution of interface pressures that occur in a selected position and can help optimize seating and positioning to minimize the risk of pressure ulcers. Research that has used pressure mapping for seating has primarily been focused on persons in wheelchairs (eg, patients with spinal injuries),[5] persons with multiple sclerosis,[6] and residents in care facilities,[4] but the benefit of pressure mapping to facilitate clinical management and minimize risk for pressure ulcers has not been examined among critically ill patients sitting out of bed.

Interpretation of results of studies that used pressure-mapping techniques to evaluate seating surfaces is difficult. Study sample sizes are often too small to show an effect, and results may not be generalizable to other settings.[6] Selection of participants has varied. Some studies have used phantom rather than human participants,[7] or healthy volunteers in laboratory settings,[8] or disabled patients.[6] The use of volunteers, with or without impairment, is likely to introduce selection bias.[9] Less-mobile individuals are at most risk of pressure ulcers developing, and therefore, samples of healthy persons are often not representative of these patients. The atrophic changes in musculature around the buttocks and thighs can increase the effects of applied pressure when seated,[10] and these effects are not observed in healthy volunteers.

> Pressure mapping may be a valuable tool for optimal positioning of intensive care unit patients sitting out of bed.

Other difficulties in interpretation of measures include problems in maintaining the same posture between measurements and reducing the effects of "creep." In-bed interface pressure with patients supine and in a range of head-elevated positions has been evaluated in the ICU but, similar to many studies, that study[11] was conducted among healthy volunteers. Nevertheless, although difficulties in comparing outcomes exist, pressure mapping has potential as a valuable tool to inform clinical practice related to optimal positioning of patients and the use of pressure-relieving aids for patients sitting out of bed in ICUs. This study was intended to (1) examine changes in seating interface pressure between different seating surfaces among ICU patients with impaired mobility sitting out of bed, (2) use this

About the Authors

Teresa Ann Williams is a nurse researcher in the critical care division at Royal Perth Hospital and an adjunct research fellow at The University of Western Australia in Perth, Western Australia. **Gavin D. Leslie** is the director of research and development at Curtin Health Innovation Research Institute, Curtin University in Perth, Western Australia. **Robert Bingham** is a senior rehabilitation engineer at Royal Perth Hospital in Perth, Western Australia. **Linda Brearley** is nursing director in the critical care division of Royal Perth Hospital in Perth, Western Australia.

Corresponding author: Teresa Williams, RN, PhD, Critical Care Division, Royal Perth Hospital, Wellington Street, Perth, Western Australia 6000 (e-mail: Teresa.Williams@health.wa.gov.au).

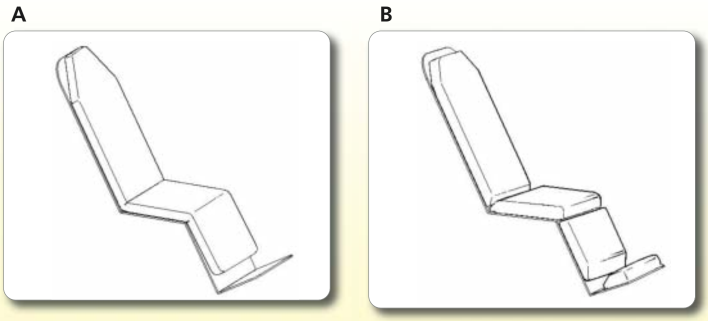

Figure 1 The regular trolley chair (A, TotaLift-II) and the alternative chair (B, Hausted APC) used for seating patients out of bed in the intensive care unit (side rails not shown).

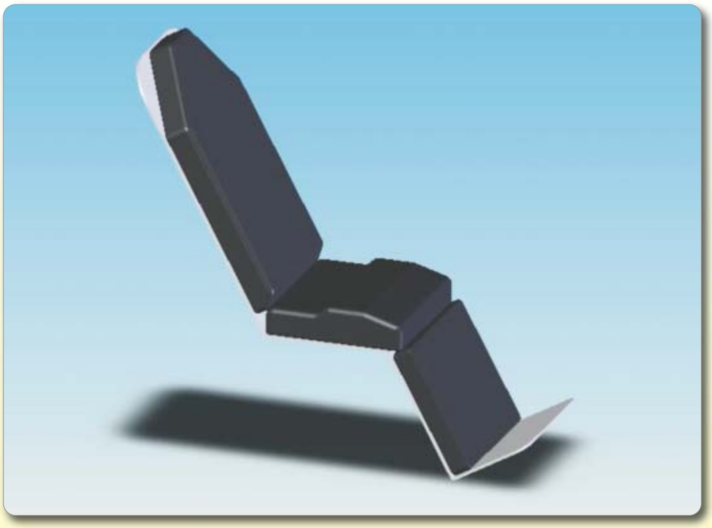

Figure 2 New surface compared with regular surface on existing chair frame in phase 2 of study.

information to inform the development of an improved seating surface, and (3) compare the seating interface pressure of the new seating surface with that of the existing surface.

Method

Study Design

Approval for the project (phases 1 and 2) was granted by the institutional ethics committee. The need to obtain written consent from patients was waived in accordance with the National Health and Medical Research guidelines, as the project represented no substantial change to patient care procedures or increased risk.[12] Each participant was given a verbal explanation of procedures as part of the process of sitting out of bed. The study was designed as a nonrandomized crossover trial in 2 phases for comparison of seating surfaces. Each patient acted as his or her own control, and seating surfaces were compared within patients, not between patients.

Participants

Patients who had impaired mobility and were scheduled to be sitting out of bed in the regular ICU chair were recruited. Patients exluded from the study were those who were unsuitable for sitting out of bed, had gross diarrhea, or were able to bear weight and therefore could sit out of bed in the ICU in a recliner rocker or high-back chair. The study was conducted in a 22-bed general ICU, a closed unit in Royal Perth Hospital, a tertiary-referral hospital in Perth, Australia. Organized turning rounds are used to position patients. Alternating airflow mattresses (Nimbus III, Huntleigh Healthcare, Perth, Australia) are used for patients in bed, except for patients with spinal injuries. Patients are sat out of bed by the nurses and/or physiotherapists with the assistance of a "turning team" as soon as their condition permits.

Process

Patients were recruited between October 2007 and May 2008 for phase 1 and between August 2008 and January 2009 for phase 2. In phase 1, 3 seating surfaces were tested: the regular chair (TotaLift-II trolley chair, Wy'East, Clackamas, Oregon), the regular chair with a gel overlay (Gel), and an alternative chair (Hausted APC, SterisCorp, Mentor, Ohio). The regular chair (Figure 1) is a trolley chair designed for surface to surface transfer of patients (a feature not shared by the alternative chair) and is suited for patients unable to bear weight, facilitating safe manual handling practices for patients and staff. Patients are transferred from the bed to the chair while supine and then the chair is moved into an upright position. Patients can be placed supine for care during the seating episode. The seating surface of the regular chair is composed of a single cushion whereas the alternative chair has 4 separate cushions. A gel overlay (45x45 cm) placed beneath the buttocks on the regular ICU chair was the third surface tested in this phase.

In phase 2, a new surface was designed (by R.B., rehabilitation engineer), informed by the results of phase 1, and was compared with the regular chair. The new surface (Figure 2) consisted of 3 cushions (back rest, cushion under the buttocks, and cushion under the legs) made from a combination of high- and low-density foam and covered with a material to limit pressure and facilitate patients' comfort. The cushion beneath the buttocks was shaped to support patients in a seated position. Preliminary testing of the new surface was conducted among 7 volunteer staff to ensure that it was safe to use before it was tried out with patients.

A seating protocol was used for both phases (Table 1). In phase 1, the decision on which seating surface was used for each seating session was determined by computer-generated random number. The randomization could not always be complied with because of the unavailability or lack of suitability of the chair, for example, some patients were too tall to be seated in the alternative chair. In both phases, the regular ICU chair was used for at least 1 seating episode for all patients. Unlike phase 1, in phase 2, seating interface pressure was measured first on the regular seating surface and second on the new surface at a subsequent session with the patient sitting out of bed. Patients who were able to do so were asked which surface was more comfortable in both phases of the study. This rating was subjective.

A Force Sensing Array (FSA version 4.0) pressure-mapping system (Vista Medical Ltd, Winnipeg, Canada) with a single standard 45x45-cm pressure map was used to measure contact pressure at the buttock-seat interface. The pressure-sensing mat contains 256 (16x16) sensors connected to the computer software (v4.1) via a type 4 interface module. Data were recorded as color-coded maps of pressure distribution, 3-dimensional grids, and numeric output parameters. The system was calibrated with an autocalibrator specific to the system and according to the instructions in the manufacturer's manual.

Table 1
Protocol used for seating patients out of bed for measurement of seating interface pressure

Step	Rationale
The pressure mat was placed on the surface and the patient positioned on the chair	To ensure entire buttocks were on the pressure pad
Initially patients were placed in an upright sitting position in the chair; hips, knees, and ankles were flexed to 90° where possible	The "normal" position as it allowed optimal weight distribution[3]
Arms were placed on the thighs to minimize the possibility that different heights of cushions would cause relative differences in armrest height	This adjustment may influence the results because 5% to 10% of the body weight is reported to be distributed through the armrests[13]
Patient's feet were positioned at 90° and the feet were supported with the chair footplate and pillows	19% of the body weight is distributed through the feet[3]
The angle of the chair backrest was measured with an inclinometer	To ensure each patient had a similar seating inclination for each seating episode

Data Collection

Data were monitored continuously, and representative frames of interface pressure maps were recorded every second, but data at 1-minute intervals were analyzed and reported for the period of 5 to 29 minutes of sitting out of bed. Data from the first 5 minutes of pressure mapping were not used, to allow for a settling-in period, and rehabilitation physiotherapy often commenced after 30 minutes. Mean interface pressures are not reported because many recordings exceeded the calibration capability of the measuring system (ie, 250 mm Hg or higher). Pressures of 200 mm Hg or higher were considered excessive on the basis of the work by Reswick and Rogers,[14] who suggested that sustained pressure should be kept below 30 mm Hg on ischii and below 100 mm Hg on thighs and that the maximum time for pressures of 200 mm Hg over bony prominences should be less than 2 hours for young, healthy volunteers. We also wanted to capture the area of highest pressure (ie, the area over the ischial tuberosities) and found that defining excessive pressures as pressures exceeding 200 mm Hg was useful for this purpose. Each patient required at least 2 sets of data for analysis. Severity of illness was estimated with the Acute Physiology and Chronic Health Evaluation (APACHE) II score (worst in first 24 hours).[15] The Braden score was used to estimate the risk for pressure ulcers.[16] Data were abstracted by the research nurse (T.W.): age, sex, APACHE II score, diagnosis, and length of stay were obtained from the ICU clinical database, and body mass index (BMI) and Braden score were obtained from the patient's nursing charts.

Organized turning rounds are used to position patients.

Data Analysis

Data analysis was conducted by using SPSS version 17.0 (SPSS, Chicago, Illinois). Continuous data are reported as medians and interquartile range (IQR). The interface pressures of the different surfaces were compared by using the Wilcoxon nonparametric test for paired data. In phase 1, 2 comparisons were made for the 3 interface pressure groups: (1) the gel surface compared with the regular chair and (2) the alternative surface compared with the regular chair. In phase 2, the regular and new surfaces were compared. Univariate logistic regression was used to examine the association of patients' characteristics with excessive pressure for patients sitting out of bed in the regular chair. Odds ratios and 95% confidence intervals were reported. Results were considered significant if the *P* value was less than .05.

Table 2
Characteristics of patients recruited in phase 1 and phase 2

Characteristic	Phase 1 (n = 18)	Phase 2 (n = 20)
Age, median (interquartile range), y	66 (59 - 73)	62 (51 - 75)
Female patients, %	28	55
Body mass index, mean (SD), range	27 (5), 20 - 35	27 (6), 17 - 43
Worst APACHE II score in first 24 hours, median (interquartile range)	17 (16 - 19)	20 (17 - 23)
Braden score, mean (SD), range	12 (2), 9 - 16	12 (2)
Most common diagnostic groups	Sepsis or pneumonia, 8 patients Trauma, 3 patients	Sepsis, 9 patients Major cardiac surgery, 3 patients
Days in intensive care unit, median (interquartile range)	14 (8 - 24)	17 (12 - 30)

Abbreviation: APACHE, Acute Physiological and Chronic Health Evaluation.

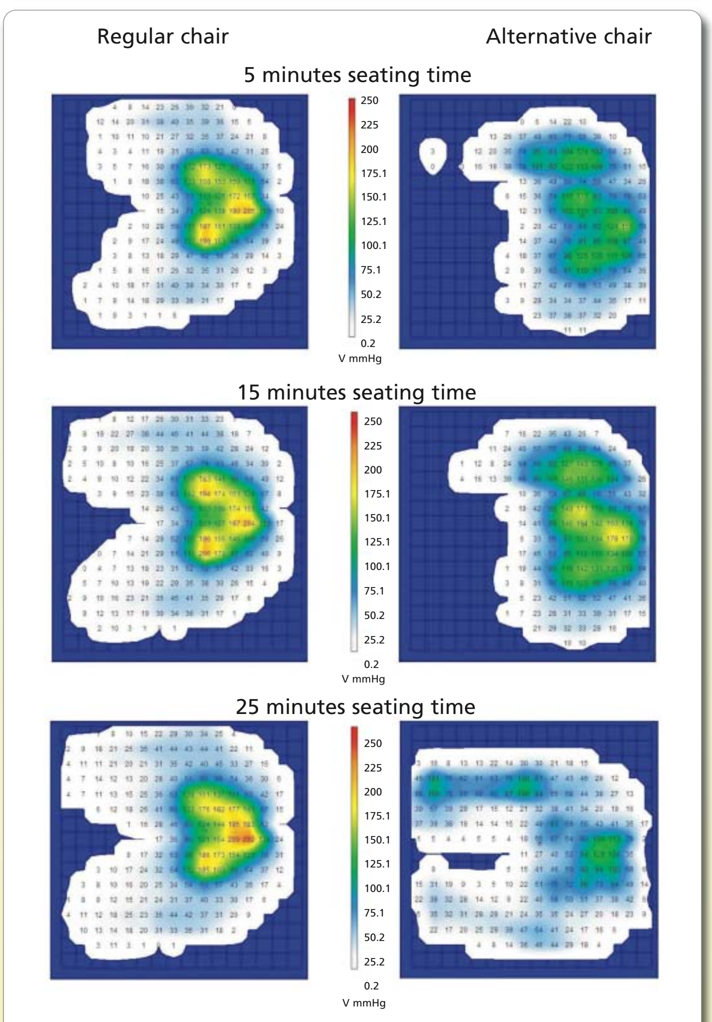

Figure 3 Pressure maps of the regular chair and alternative chair at 5, 15 and 25 minutes for a typical patient. The scale for pressure (mm Hg) ranges from white (lowest pressure) to red (highest pressure).

Results

Phase 1

Eighteen patients had at least 2 sets of analyzable data (11 patients had data for 3 surfaces, 7 patients had data for regular chair and gel surfaces). The median age was 66 years and most patients (72%) were male (Table 2). Among the 18 patients, 8 were admitted for sepsis/pneumonia and 3 were admitted with trauma. The median length of stay was 14 days. The median APACHE II score was 17, and the mean Braden score was 12. The mean BMI was 27.

For the 18 patients, 53 seating surface measurement periods (1532 pressure maps) were compared. Pressure mapping was conducted for up to 120 minutes. One patient had to be put back to bed within minutes of starting to sit out of bed because of hypotension, and this seating episode was not mapped. No other events were encountered. An example of the pressure maps used to compare the regular chair and alternative chair at 5, 15, and 25 minutes of sitting out of bed is shown in Figure 3.

For patients who had pressure maps that showed excessive pressures (≥200 mm Hg), 46% of pressures recorded for the regular chair were higher than pressures for the gel chair, and on 11% of maps, the pressures were similar for the regular and gel seating surfaces ($z = 2.0$, $P = .04$). In comparison, the alternative chair had significantly fewer excessive seating interface pressures compared with the regular chair (67% of regular surfaces had higher pressures than the alternative surface, $z = 4.0$, $P < .001$), whereas 7% had similar interface pressures for both surfaces. Patients who were able to do so indicated that the alternative chair was more comfortable than the regular chair, and 2 patients refused to sit on the regular surface after sitting on the alternative surface. The alternative chair also had fewer excessive pressures (69% of surfaces) when compared with the gel overlay ($P < .001$). However, the alternative chair lacked the practical utility of the regular chair, as it was difficult to manage transfer of patients from bed to chair and the alternative chair had limited adjustment options for supporting the patient once out of bed. The gel overlay did not reduce seating interface pressures. It was concluded that no surface addressed all requirements for patients sitting out of bed, and therefore a new surface was designed to be adapted to our original chair.

Phase 2

Because the alternative chair was considered unsuitable for our ICU (eg, it had no built-in slide board facility, minimal footplate adjustment) and little benefit was seen with the gel surface, the new surface was compared only with the old surface by using the existing chair frame for both. The 2 surfaces were assessed among 7 volunteer ICU staff for practicality and safety before being introduced to the patient cohort. Interface pressures were assessed and revealed significant differences between them ($P < .005$ for all t-test paired comparisons) in favor of the new surface. The highest peak interface pressures were 90 to 101 mm Hg for the regular and 70 to 78 mm Hg for the new surface. The volunteers all remarked that the new seating cushions were more comfortable than the regular ICU chair.

Twenty phase 2 participants had at least 2 sets of analyzable data, with slightly more women (55%) than men. The median age was 62 years, and length of stay in the ICU was 17 days (Table 2). The median worst APACHE II score in 24 hours was 20. The mean Braden score was 12, and the mean BMI was 27.

More than half (55%) of the patients had seating interface pressures of 200 mm Hg or greater (excessive pressures), and of these 11 patients, 10 (93%) had fewer episodes of excessive pressures on the new surface ($z = -4.2$, $P < .001$). Nine patients had pressures of 200 mm Hg or higher at 5 minutes of sitting, and the excessive pressures were present in all members of this subgroup by 7 minutes of sitting out of bed. An example of the pressure maps that compares the regular surface with the new surface at 5, 15, and 25 minutes of sitting is shown in Figure 4. No events occurred that required return to bed or dissatisfaction with the new seating surface in phase 2. Patients able to do so indicated that the new surface was more comfortable.

For the remaining 9 patients, seating interface pressures were lower than 200 mm Hg. Among patients who had pressures of 150 to less than 200 mm Hg, 40% had fewer episodes of higher interface pressure with the new surface than with the regular surface ($z = -7.1$, $P < .001$), 28% had similar interface pressures on either surface, and the remaining 32% had higher pressures on the new surface.

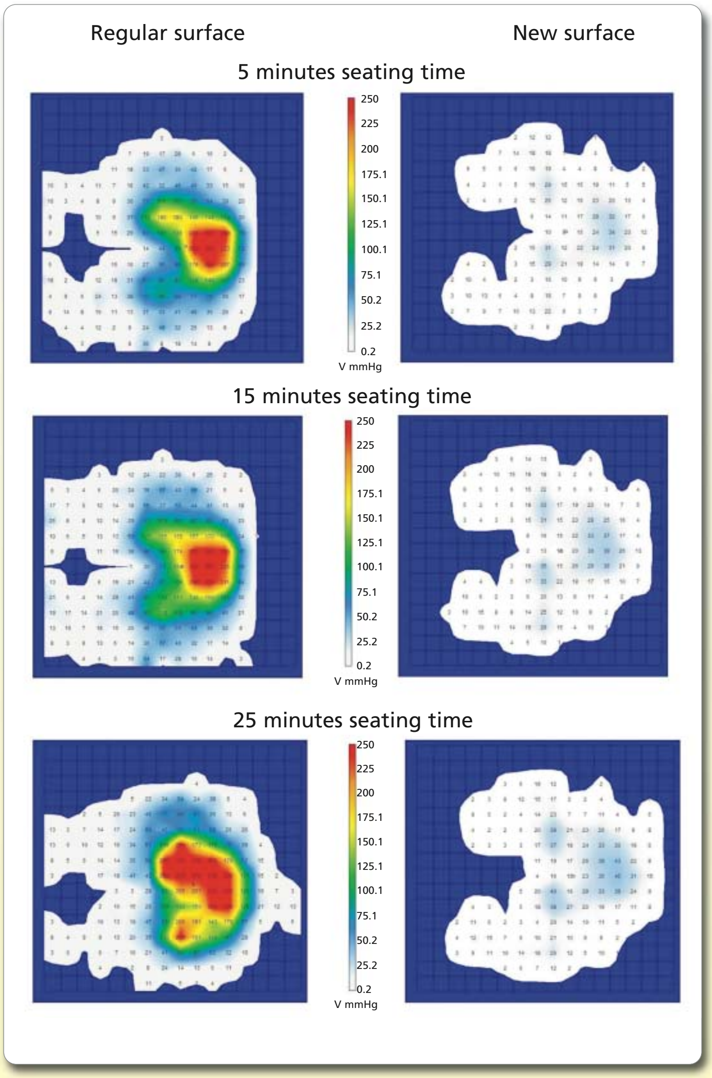

Figure 4 Pressure maps of the regular surface and new surface at 5, 15, and 25 minutes for a typical patient. The scale for pressure (mm Hg) ranges from white (lowest pressure) to red (highest pressure).

The only factor (unadjusted) that was associated with excessive pressures when seated on the regular chair was the patient's sex. Women (odds ratio, 0.12; 95% confidence interval, 0.03-0.59) were less likely to experience excessive pressures (Table 3). Age, APACHE II score, BMI, and Braden score were not significantly associated with excessive pressures. Women and men (n = 38) were similar for age, APACHE II score, Braden score, and BMI (P values ranged from .80 to .97; mean age, 64 years for women vs 63 years for men; mean APACHE II score, 22 for women vs 21 for men; mean Braden score, 12.3 for both women and men; and BMI, 27 for both women and men).

Table 3
Results of the univariate logistic regression (n = 38) of the association of patient characteristics with excessive seating interface pressures (≥200 mm Hg) for patients seated on the regular chair

	Odds ratio	95% Confidence interval	*P*
Age, for each year increase in age	1.06	1.00 - 1.20	.05
Female patients	0.12	0.03 - 0.59	.01
Mean body mass index, for each point increase	0.97	0.85 - 1.11	.63
Worst APACHE II score in first 24 hours, for each point increase	1.04	0.95 - 1.13	.45
Braden score, for each point increase	0.91	0.66 - 1.24	.54

Abbreviation: APACHE, Acute Physiological and Chronic Health Evaluation.

Discussion

This study showed for the first time that most ICU patients sitting out of bed experience high seating interface pressures, and the cushions used to support critically ill patients have significantly different seating interface pressures. Furthermore, high pressures are often experienced early in the episode of sitting out of bed and are often sustained for the duration of the seated period. Practical design features, which include other considerations such as occupational risk reduction in moving patients and positioning devices such as adjustable footboards, are also important in any chair for vulnerable ICU patients sitting out of bed.

Intensive care unit patients sitting out of bed experience high seating interface pressures.

None of the tested surfaces in phase 1 of our study combined lower interface pressures with the required design features for a chair to sit ICU patients out of bed. Consequently, a new surface was developed that could be used with the existing chair frame. Although we found high interface pressures with all surfaces assessed, we found significantly fewer episodes of excessive seating interface pressures with the new surface. These findings are important for promoting patients' comfort and managing patients sitting out of bed in the ICU.

Researchers in 2 studies[11,17] have used pressure mapping to examine interface pressure for ICU patients but, to our knowledge, no one has evaluated the seating interface pressures for patients sitting out of bed in the ICU. Sakai and colleagues[17] assessed the feasibility of continuous interface pressures among 30 postoperative patients in ICU while the patients were in bed for up to 48 hours. They report the technique as feasible, although they excluded emergency admissions and the very ill patients who constitute a substantial proportion of ICU patients.

Pressure ulcers are debilitating and costly.[18] Risk assessment and implementation of minimization strategies for pressure ulcers include pressure-relieving surfaces,[19] reduction of mechanical load, appropriate skin care and control of moisture,[20] and adequate nutrition. The majority of these recommendations are based on expert opinion and consensus rather than controlled trials. Appropriate seating surfaces are crucial to ameliorate the risk for pressure ulcers and should be selected on the basis of the needs and characteristics of the patient.[21,22] None of the patients in this study had pressure ulcers develop once they started sitting out of bed, but we could not determine if pressure ulcers were caused by sitting out of bed after the ICU, and most patients in the study were discharged to the general care area soon after they were able to sit out of bed. Comfort and minimizing the risk for pressure ulcer development are particularly important for these patients because they are likely to have a long recovery phase that includes regularly sitting out of bed.

The volunteer staff participants had comparatively lower seating interface pressures with the new surface and reported it to be subjectively more comfortable. Interestingly, the seating interface pressures on both surfaces for the volunteers were considerably lower than those for most patients sitting out of bed in the ICU. These results provide further evidence of the lack of generalizability between the "healthy volunteer" and the critically ill patient in this context and might partly be explained by factors such as sedation of the patient, debilitated condition, and nutritional status.

We were able to translate our research findings directly into practice. Although the alternative chair had lower seating interface pressures, it lacked clinical utility. There was no built-in slide-board, which facilitates transfer of patients and reduces occupational injury of staff involved in manual handling of patients. As a result of the study, a decision was made not to purchase the alternative chair because it did not meet all the seating needs of the patients in our ICU. The useful features of the regular ICU chair were then incorporated with the new seating surface that could be used on the existing chair frame.

This study had several limitations. We anticipated that we would be able to recruit 20 patients within 6 months in phase 1. However, recruitment was restricted to business hours because of the availability of equipment and technical staff and did not include patients once they were transferred to the general care area or patients who were well enough to sit in a recliner rocker or high-back chair. As a consequence, recruitment was slow.

The potential for error in measurement of interface pressure is an important consideration. Pressure mapping is a comparative tool. Patients were used as their own controls to compare interface pressures between surfaces so as to limit variation in physical characteristics that would have been a factor if between-patient analyses were used. The contributions of factors such as shear that cannot be measured by pressure mapping are important.

We made every effort to reduce errors. Nevertheless, pressure mapping is only one tool in the assessment of risk for pressure ulcers. Peak mean pressures or the standard deviation are commonly used in the reporting of interface pressure. The calibration of the FSA equipment is limited to 250 mm Hg, and many of our patients experienced seating interface pressures of at least 250 mm Hg. We therefore compared the area of highest pressure by comparing the number of cells with excessive pressure (≥200 mm Hg) between surfaces for each patient. This strategy also minimized the bias from the differences in the contact area that occurred from the use of different seating surfaces. As only 9 patients had excessive pressure in phase 2, we then compared the number of cells registering pressures between 150 and 200 mm Hg. Measuring these pressures did not adequately capture the areas of peak pressure. Sixty-eight percent of the patients had lower or similar interface pressures with the new surface whereas nearly a third of patients (32%) had lower pressures with the old surface in this range. Pressure mapping provides information about individual patients based on their unique physical attributes. Patients may assume different seating postures between seating episodes. In addition, seating patterns vary on different surfaces. We used a seating protocol for sitting patients out of bed and maintained a similar inclination of the chair to minimize these effects.

Conclusion

Consideration of strategies for minimizing pressure ulcers, including appropriate seating surfaces for patients sitting out of bed in the ICU, is important. A combination of low- and high-density foam covered with pressure minimization material and the use of multiple cushions were key elements of our new seating surface. Evaluation of seating surfaces in the ICU by using interface pressure measurement is an important component of a quality initiative to optimize seating for critically ill patients and has utility within the wider hospital community, but further research is needed.

ACKNOWLEDGMENTS
We thank the physiotherapists and nursing staff in the ICU at Royal Perth Hospital and Huntleigh Health Care for extending their trial period of the Steris HAUSTED APC chair.

FINANCIAL DISCLOSURES
The work undertaken in this study was supported by the Western Australian Department of Health's Safety and Quality Investment for Reform project, which funded T.A.W. during the study period.

eLetters
Now that you've read the article, create or contribute to an online discussion on this topic. Visit **www.ajcconline.org** and click "Respond to This Article" in either the full-text or PDF view of the article.

REFERENCES
1. Cullum N. Pressure ulcer prevention and treatment: a synopsis of the current evidence from research. *Crit Care Nurs Clin North Am.* 2001;13:547-554.
2. Thompson D. A critical review of the literature on pressure ulcer aetiology. *J Wound Care.* 2005;14:87-90.
3. Collins F. Use of pressure reducing seats and cushions in a community setting. *Br J Comm Nurs.* 2002;7:15-22.
4. Geyer MJ, Brienza DM, Karg P, Trefler E, Kelsey S. A randomized control trial to evaluate pressure-reducing seat cushions for elderly wheelchair users. *Adv Skin Wound Care.* 2001;14:120-129.
5. Sprigle SH, Faisant TE, Chung KC. Clinical evaluation of custom-contoured cushions for the spinal cord injured. *Arch Phys Med Rehab.* 1990;71:655-658.
6. Crawford SA, Stinson MD, Walsh DM, Porter-Armstrong AP. Impact of sitting time on seat-interface pressure and on pressure mapping with multiple sclerosis patients. *Arch Phys Med Rehab.* 2005;86:1221-1225.
7. Fader M, Bain D, Cottenden A. Effects of absorbent incontinence pads on pressure management mattresses. *J Adv Nurs.* 2004;48:569-574.
8. Stinson M, Porter A, Eakin P. Measuring interface pressure: a laboratory-based investigation into the effects of repositioning and sitting. *Am J Occup Ther.* 2002;56:185-190.
9. Kernozek TW, Wilder PA, Amundson A, Hummer J. The effects of body mass index on peak seat-interface pressure of institutionalized elderly. *Arch Phys Med Rehab.* 2002;83:868-871.
10. Swain ID, Bader DL. The measurement of interface pressure and its role in soft tissue breakdown. *J Tissue Viability.* 2002;12:132-134.
11. Peterson M, Schwab W, McCutcheon K, van Oostrom JH, Gravenstein N, Caruso L. Effects of elevating the head of bed on interface pressure in volunteers. *Crit Care Med.* 2008;36:3038-3042.
12. National Health and Medical Research Council. National Statement on Ethical Conduct in Research Involving Humans. 2007. http://www7.health.gov.au/nhmrc/publications/_files/e35.pdf. Accessed August 1, 2007.
13. Burns SP, Betz KL. Seating pressures with conventional and dynamic wheelchair cushions in tetraplegia. *Arch Phys Med Rehabil.* 1999;80:566-571.
14. Reswick J, Rogers J. Devices and techniques to prevent

pressure sores. In: Kenedi R, Cowden J, Scales J, eds. *Bed Sore Mechanics.* London: The Macmillan Press Ltd; 1976.
15. Knaus WA, Draper EA, Wagner DP, Zimmerman JE. APACHE II: a severity of disease classification system. *Crit Care Med.* 1985;13:818-829.
16. Braden BJ, Bergstrom N. Clinical utility of the Braden scale for predicting pressure sore risk. *Decubitus.* 1989;2:44-46.
17. Sakai K, Sanada H, Matsui N, et al. Continuous monitoring of interface pressure distribution in intensive care patients for pressure ulcer prevention. *J Adv Nurs.* 2009;65:809-817.
18. Russo C, Elixhauser A. Hospitalizations related to pressure sores, 2003. Healthcare Cost and Utilization Project. Statistical Brief #3. 2006. http://www.hcup-us.ahrq.gov/reports/statbriefs/sb3.pdf. Accessed October 25, 2010.
19. National Pressure Ulcer Advisory Panel. Support Surface Standards Initiative. Terms and defintions related to support surfaces. 2007. http://www.npuap.org/NPUAP_S3I_TD.pdf. Accessed October 25, 2010.
20. Thompson P, Langemo D, Anderson J, Hanson D, Hunter S. Skin care protocols for pressure ulcers and incontinence in long-term care: a quasi-experimental study. *Adv Skin Wound Care.* 2005;18:422-429.
21. Reddy M, Gill SS, Rochon PA. Preventing pressure ulcers: a systematic review. *JAMA.* 2006;296:974-984.
22. Ooka M, Kemp MG, McMyn R, Shott S. Evaluation of three types of support surfaces for preventing pressure ulcers in patients in a surgical intensive care unit. *J Wound Ostomy Continence Nurs.* 1995;22:271-279.

To purchase electronic or print reprints, contact The InnoVision Group, 101 Columbia, Aliso Viejo, CA 92656. Phone, (800) 899-1712 or (949) 362-2050 (ext 532); fax, (949) 362-2049; e-mail, reprints@aacn.org.