

Intraoperative Pressure Sore Prevention: An Analysis Of Bedding Materials

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The relationship between operating room (OR) table surfaces and skin integrity was examined. Preoperatively, patients (N = 505) were rated for pressure sore potential (Hemphill); post-operatively, skin condition was assessed. Skin changes were more likely with a standard mattress only or with surgery longer than 2.5 hr. The overlay was more effective than the foam and gel or standard foam mattresses for preventing pressure sore formation. Factors predictive of pressure sore development included surgery of 2.5+ hr., 40+ years, vascular disease, and a preoperative Hemphill value of 4+. Patient characteristics, surgical experience variables, and OR table surfaces are determinants in pressure sore development. ©1994 John Wiley & Sons, Inc.

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Intensity and duration of pressure have been reported to be critical primary components in the etiology of pressure sore formation (Braden & Bergstrom, 1987). Indeed, a synergistic relationship has been demonstrated between these two variables, such that high pressure of short duration or lower pressure for longer durations may be equally damaging to the tissue. Landis (1930) determined that end arterial capillary pressure averaged 32 mm Hg. This value is currently accepted as the external threshold pressure beyond which small vessels collapse and thrombose, resulting in occluded blood flow with consequent deprivation of oxygen, nutrients, and lymph circulation. Toxic metabolites are produced at the cellular level, leading to tissue acidosis, increased capillary permeability, edema, cell death, and resultant pressure sore formation (Maklebust, 1987).

Secondary factors contributing to pressure sore formation may be intrinsic or extrinsic. Factors intrinsic to the patient include decreased nutrition, increased age, sensory loss, chronicity, impaired mobility, decreased mental status, and incontinence (Gosnell, 1987). Extrinsic factors include shear force, friction, and pressure (Copeland-Fields & Hoshiko, 1989). Factors specific to the intraoperative phase identified as contributing to pressure sore formation have included weight, type of anesthesia, length of surgery, and thermal blanket usage (Campbell, 1989). Kemp, Keithley, Smith, and Morreale (1990) identified time on the operating room (OR) table, extracorporeal circulation, and age as the most predictive factors in intraoperative pressure sore formation.

Wide variance is reported in the frequency of and costs incurred by pressure sores. The overall incidence of pressure sore formation during operative procedures has been identified as 12% (Kemp et al., 1990). In all hospitalized patients, pressure sore development has been reported to range from 5% (Abruzzese, 1985) to 66% in elderly patients with femoral neck fractures (Versluysen, 1986). Moreover, costs related to pressure sore care and resolution in all hospitalized patients have been estimated to range from \$5000 to \$40,000 (Curtin, 1984).

Such wide ranges in cost and rate of occurrence may be attributed, at least in part, to the differences in the definition of pressure sores. The National Pressure Ulcer Advisory Panel (NPUAP, 1989) was convened to focus attention on a number of issues surrounding pressure ulcers. The panel reduced discrepancies in the definition of pressure sores by combining commonly used systems in the creation of a more universal classification system:

Stage I - nonblanchable erythema of intact skin

Stage II - partial thickness skin loss of epidermis and/or dermis

Stage III - full-thickness skin loss involving damage of the subcutaneous tissue down to fascia

Stage IV - full-thickness skin loss with tissue destruction to muscle, bone, or supporting structures (NPUAP, 1989)

Products available to prevent pressure sore formation include those that reduce pressure and those that relieve pressure. Pressure reduction devices lower interface pressures between tissues and surfaces, but do not consistently maintain pressure below the 32 mm Hg capillary closure point. In contrast, pressure relief devices consistently maintain the tissue and surface interface pressure below 32 mm Hg., thus assuring tissue perfusion at the capillary level (Klein & Gilroy, 1989).

Pressure reduction devices currently available include foam- or air-filled mattresses and water or gel filled overlays.

Pressure reduction products may be further classified as static or dynamic. Static devices are designed to provide dry flotation, while dynamic devices involve a pump or motor which cycles to provide constantly changing pressure points beneath the patient. Intraoperatively, static devices are preferable to insure stability at the surgical site. In contrast, pressure relief devices are air fluidized or low airloss specialty care beds, none of which are well suited for operating room use.

The surgical environment offers unique opportunities for investigating and developing effective pressure reduction and relief devices. Because the patient cannot move during surgery and is carefully placed in a particular position for each procedure, a product should be stable, firm, should distribute pressure evenly without any "bottoming out" effect, should conform to the patient's body, and should be available in many shapes and sizes. Due to the myriad pieces of equipment and frequent use of electrosurgical devices and lasers, the product should be flame and leak resistant, and would best have no extra cord. To contribute to infection control, the product should be resistant to infectious growth. To protect skin, the product should disperse moisture and be nonallergenic. In addition, environmental concerns would be met if the product were reusable, thereby decreasing the amount of materials reaching landfills. The reduction of tissue and surface interface pressure below 32 mm Hg., however, is of paramount importance (Doughty, Fairchild, & Stogis, 1990). Gel-filled overlays and replacement mattresses designed specifically for the OR table possess these characteristics; however, the efficacy of these products in preventing intraoperative pressure sore formation has not been examined. Therefore, the purposes of this quasi-experimental study were to: (a) examine and effects of two OR table mattresses and one mattress overlay on intraoperative pressure sore formation, and (b) identify factors predictive of alterations in skin integrity during the intraoperative period.

METHOD

Sample

A convenience sample of 505 patients was selected from the weekday operative schedule of a large university teaching hospital and were randomly assigned to one of six experimental groups. The three criteria for including patients in the study were placement in the supine or prone positions while undergoing surgery, older than 12 years of age, and possession of symmetrical lower limbs. Human subjects criteria were met and the study was approved by the Institutional Review Board. All surgeons gave written consent enabling patients to participate; verbal consent was obtained from patients prior to inclusion in the study.

The 505 patients consisted of 321 women (63.6%) and 184 men (36.4%). Ages ranged from 13 to 86 years, with a mean of 47 years (SD = 17.1). Preexisting vascular disease, hypertension, and diabetes mellitus were present in 32 (6.3%), 103 (20.4%), and 38 (7.5%) patients, respectively. Patients currently smoking comprised 120 (23.8%) of the sample, while an additional 12 (2.4%) had a past history of smoking. Of the patients, 173 (34.3%) underwent a general surgical procedure, 107 (21.2%) had otolaryngologic, 81 (16%) orthopedic, 56 (11%) gynecological, 36 (7.1%) vascular, 21 (4.2%) neurosurgical, 16 (3.2%) urological, and 15 (3%) dental procedures. The majority of

patients, 336 (66.5%), underwent general anesthesia, 77 (15.2%) had local anesthesia, 61 (12.1%) received sedation with local anesthesia, 27 (5.3%) had a regional nerve block, and 4 (0.8%) received spinal or epidural anesthesia. Time on the OR table was recorded to be < 1 hr for 145 (29.7%), 1 to 2 hr for 151 (29.9%), 2 to 4 hr for 134 (26.5%), 4 to 6 hr for 53 (10.5%), 6 to 8 hr for 16 (3.2%) and > 8 hr for 6 (1.2%) of the patients.

Measures

An adaption of *Hemphill's Guidelines for Assessment of Pressure Sore Potential* was used preoperatively to assign numerical values to patient risk for developing pressure sores. (Hemphill, 1986). This instrument consists of seven ratable areas: (1) general physical condition, (2) mental status, (3) activity, (4) mobility, (5) incontinence, (6) nutrition/fluid intake, and (7) existing skin condition. Total point values range from 0 to 34, with a higher value indicating a greater risk for pressure sore development.

General physical condition values were assessed as *no major health problems* (0), *controlled health problems* (1), and *one or more acute or chronic serious health problems*, such as uncontrolled diabetes or advanced vascular disease (2). *Mental status* values ranged from 0 to 3, going from *alert and oriented* (0), *lethargic and sleepy* (1), *confused and uncooperative* (2), to *comatose* (3). Activity values ranged from 0 to 6, progressing from *ambulatory* (0), *assisted walking* (1), *confined to chair or wheelchair* (4), to *bedfast* (6). *Mobility* was assessed as *full* (0), *limited movement* (1), *movement only with assistance* (4), and *immobile* (6).

Incontinence was assessed as *none or contained by ostomy or foley* (0), *occasional bladder loss* (1), *no bladder control and occasional fecal soiling* (4), or *no bladder control and frequent fecal soiling* (6). *Nutrition and fluid intake* was assessed as *adequate food and fluid intake or hyperalimentation, and weight within normal limits* (0), *encouraged food and fluid intake or tube feedings, or underweight or overweight* (1), *poor food and fluid intake, or weight loss* (2), *unable or unwilling to take oral food and fluids* (3). *Existing skin breakdown* was assessed as *none* (0), *reddened area* (4), *blister or skin break of any kind* (8) (Hemphill, 1986).

The level of risk associated with total point values was "low" (0-12), "moderate" (13-25), and "high" (26 or above). The scale was adapted slightly for use throughout the institution by the addition of items commonly encountered in the hospital setting, such as "acute" serious health problems under general physical condition, "ostomy" and "Foley" under incontinence, "hyperalimentation" and "tube feedings" under nutrition and fluid intake.

The *Hemphill* scale was already being used throughout the institution and throughout the immediate metropolitan area at the time of the study. It was chosen for use because of its comprehensiveness, its simplicity, and its assurance of systematic patient assessment. Face and content validity for the *Hemphill* scale was provided by four enterostomal therapists who agreed that the tool contained essential elements for measuring the risk for potential pressure sore development. Interrater reliability between the two primary researchers was 0.987.

Procedure

The effects of three products on preventing intraoperative pressure sores were examined in this study: (1) a standard vinyl covered 2-inch thick foam OR table mattress (SFM), (2) a nylon fabric covered 2-inch thick foam and gel OR table mattress (FGM - *Akros*®, American Sterilizer Co.), and (3) a viscoelastic dry polymer mattress overlay (VEO-Action® , Action Products Inc.). Paired comparisons of patients' right and left heels or knees were used to test the effectiveness of six different combinations of the mattresses and overlay. This paired comparisons approach allowed for each patient to serve as his/her own control, eliminating the effect of group disparity and thereby minimizing sample size. Patients were randomly assigned to one of six mattress/overlay combinations: (1) SFM versus FGM (n = 91), (2) VEO above SFM versus FGM (n = 92), (3) SFM versus VEO above FGM (n = 62). (4) VEO above SFM versus VEO above FGM (n = 113), (5) SFM

versus VEO above SFM (n = 73), and (6) FGM versus VEO above FGM (n = 74).

Subjects were interviewed and charts were inspected preoperatively to determine demographic data, including age, sex, weight, the presence of vascular disease or diabetes mellitus, serum albumin level, and history of smoking.

Preoperatively, patients' heels and knees were visually inspected by the researchers for the absence or presence of skin breakdown, and a pressure sore potential rating was assigned. The investigators tested the revised Hemphill tool for interrater reliability by examining independently the first 55 patients for pressure sore potential. A Pearson *r* correlation yielded a value of 0.987, which indicated that the primary researchers were able to administer the tool equivalently. Thereafter, a single researcher completed the preoperative assessment of pressure sore potential for each patient.

In the operating room, the OR tables were prepared with the various mattress and overlay combinations under the heel or knee sections prior to patient occupancy. In order to accommodate the various surgical positions, an OR table normally is fitted with three mattress sections which correspond in size with the head, torso, and foot sections of the table and which are secured to the table by velcro strips. The foot section of the table was always affected because the patient's heels or knees always rest in this area. The mattresses used during the study were head sections which together occupied the same amount of space as a single foot section. If the mattress/overlay combination required that the mattresses differ, the two head sections were placed vertically side by side and were secured to the table surface by velcro. If the combination required one type of mattress and the overlay, the overlay simply covered half of the mattress. Mattresses were covered by linen when used alone; otherwise, the overlay was placed above the mattress in contact with the skin and in accordance with manufacturer recommendations. Patients were then transferred to the OR table. Surgical specialty, type of anesthesia, supine or prone position, extracorporeal circulation, thermal blanket use, and application of compression stockings were recorded.

Postoperatively, the researchers visually inspected patients' heels and knees for color, blanching, and existing skin breakdown. The researcher completing the postoperative assessment differed from the person assessing the patient preoperatively whenever possible. All skin changes were noted, whether or not they were sufficient to be rated as a Stage I pressure sore, for purposes of determining mattress and overlay effectiveness. Blanchable hyperemic areas were classified as skin changes and nonblanchable hyperemic areas were classified as Stage I pressure sores, in accordance with the NPUAP staging system. Total time on the OR table was recorded for each patient.

Data Analysis

A logistic regression was performed to determine the patient characteristics and surgical experience variable which were predictive of and the mattress and/or overlay interventions which were preventive of alterations in skin integrity. This analysis was useful for determining the impact of a large number of variables while controlling for the interaction effects. Thus, it incorporated the independent variables (six mattress and/or overlay combinations), the dependent variables (no skin changes, skin changes less than Stage I pressure sores, and Stage I pressure sores), individual patient characteristics (gender, weight, age, hypertension, vascular disease, diabetes mellitus, smoking), variables related to the surgical experience (time on the OR table, type of anesthesia, application of compression stockings, or thermal blanket), and the preoperative Hemphill scale rating. The logistic regression results were expressed in terms of odds ratios, which indicated the likelihood of (a) patient and surgical experience characteristics contributing to skin changes or pressure sore development, and (b) mattress and/or overlay combinations preventing such alterations in skin integrity from occurring.

RESULTS

None of the 505 patients developed pressure sores of severity Stages II through IV in the

immediate postoperative period. Stage I pressure sores occurred in 85 patients (16.8%), with 72 patients (14.3%) exhibiting unilateral and 13 (2.6%) experiencing bilateral changes. Skin changes that did not reach Stage I occurred in 290 patients (57.4%). The logistic regression, which controlled for differences between the independent and dependent variables as well as disparity in patient characteristics, surgical experience variables, and preoperative Hemphill scale ratings, yielded sub-groups which seemed to occur naturally in the data distribution, and included time on the OR table (0-2.5 hr, 2.5-4 hr, and 4 or more hr), age (13-40 years, 41-70 years, and 70 or more years), and preoperative Hemphill scale rating (1-3 points and 4 or more points). In relation to skin changes, two independent variables and one surgical experience variable emerged from the logistic regression as being significant ($p < 0.01$). Both the foam and gel mattress and the viscoelastic overlay were more effective than the standard foam mattress for preventing skin changes. The single factor predictive of skin changes was the surgical experience variable of time on the OR table greater than 2.5 hr (Table 1).

Factor	Odds Ratio	Confidence Limits (95%)	p Value
Viscoelastic Overlay	0.16	0.10 - 0.24	<0.001
Foam and gel Mattress	0.49	0.34-0.72	<0.001
Time on OR Table			
2.5-4 h	2.42	1.64-3.59	<0.001
> 4 h	2.97	1.86-4.75	<0.001

In relation to pressure sore formation, however, one independent variable, one surgical experience variable, two patient characteristic variables, and the preoperative Hemphill scale rating were significant ($p < 0.05$). The viscoelastic overlay was more effective than either the foam and gel or standard foam mattresses for preventing pressure sore formation. Factors predictive of pressure sore formation included time on the OR table longer than 2.5 hr, presence of vascular disease, age over 40 years, and a preoperative Hemphill scale rating of 4 or more (Table 2).

DISCUSSION

The findings provide important insights regarding intraoperative skin care management. The logistic regression results lead to the conclusion that the OR table surface does affect patient risk

Factor	Odds Ratio	Confidence Limits (95%)	p Value
Viscoelastic Overlay	0.40	0.21-0.77	<0.006
Time on OR Table			
2.5-4 h	2.06	1.10-3.87	<0.02
> 4 h	5.10	2.60-9.99	<0.001
Vascular disease	2.37	1.10-4.89	<0.02
Age			
41-70 years	2.13	1.16-3.89	<0.01
> 70 years	3.37	1.46-7.81	<0.0005
Hemphill scale Rating > 4	2.89	1.25-6.69	<0.01

for development of skin changes and formation of pressure sores. When considering mattress and

overlay effectiveness, both the foam and gel mattress and the viscoelastic overlay were significantly better for preventing skin changes than was the standard foam mattress. Furthermore, the overlay offered significantly better protection against the development of pressure sores than did either mattress alone when patients were over 40 years of age, or had vascular disease, or were on the OR table longer than 2.5 hr.

Ideal bedding characteristics for use in the operating room have heretofore been identified to include stability, firmness, pressure reduction, and the ability to distribute pressure evenly without "bottoming out." When comparing the standard foam mattress with the foam and gel mattress, the addition of gel appears to improve pressure distribution. However, it is also important to note that the two mattresses differ in their cover materials. Indeed, the softer nylon cover of the foam and gel mattress appears to be an improvement over the firmer vinyl covering of the standard foam mattress, which may negate some of its pressure-reducing effects. Because both the foam and gel mattress and the viscoelastic overlay are stable and firm, it would seem that the difference between these products is associated with the overlay's superior ability to distribute pressure and to avoid "bottoming out."

The findings support and extend the body of knowledge related to the identification of specific patient characteristics which are predictive of changes in skin condition during the intraoperative phase. Kemp et al. (1990) identified age as one of three critical determinants which contribute intraoperatively to alterations in skin integrity, and Campbell (1989) associated age over 50 years and vascular disease with an increased incidence of pressure sore development. Kemp's results did not correlate any particular age with increased risk of pressure sore formation, yet they concluded that further research should address the relationship between pressure sore formation and age. In contrast to Campbell's findings that pressure sores commonly occurred in patients over 50 years, patient risk for developing pressure sores in this study doubled after age 40 and tripled after age 70. While Campbell's (1989) work was restricted to patients having peripheral vascular surgery, our results indicated that patients having vascular disease were twice as likely to develop a pressure sore than those individuals without a history of vascular disease, regardless of the surgical procedure.

The findings also support and extend the body of knowledge related to the identification of specific surgical experience variables which are predictive of changes in skin condition during the intraoperative phase. Although Campbell (1989) identified time on the table as an important component in the intraoperative etiology of pressure sores, this was limited to a progressive increase in pressure over sacral prominences over time. Kemp et al. (1990) reported that time on the table was not significant for pressure sore development unless it was combined with other predictors. Our results indicate that 2.5 hr to 4 hr doubles the risk of skin changes and pressure sore formation, whereas 4 hr or more triples the risk of skin changes and quadruples the risk of pressure sore development. Kemp et al. (1990) also identified an association between extracorporeal circulation and pressure sore development. In the current study, we were unable to assess the impact of extracorporeal circulation due to lack of access to patients undergoing cardiac bypass procedures.

Although previous investigators have examined factors which contribute to the development of pressure sores in the intraoperative setting, little has been done to determine which currently available products may decrease such complications. The results of this study can be used initially by OR managers to guide purchasing decisions. Findings indicate that the foam and gel mattress is effective for preventing skin changes, while the viscoelastic overlay is effective for preventing both skin changes and pressure sore formation. "Just as there are costs associated with treating pressure sores, there are costs associated with preventing them" (Kemp et al., 1990, p. 300), and both products are more costly than a standard foam mattress, with the overlay being the costlier investment. If the goal is to reduce the risk of skin changes in settings such as short procedure units where patients are younger and not seriously ill, and surgeries last less than 2.5 hr, the foam and gel mattress would be sufficient. However, in tertiary care settings, where patients may be older and have more serious or chronic health problems, where vascular disease is more prevalent,

and surgical procedures frequently extended beyond 2.5 hr, the viscoelastic mattress overlay appears to offer the most benefit. If the goal in either setting is to minimize pressure sore formation, the foam and gel mattress offers no real improvement over a standard foam mattress. The results of this study can also be used by practitioners to assess and to position individual patients intraoperatively, based on the identified patient characteristics which increase the risk of alterations in skin integrity, and the expected length of time for the surgical procedure.

Limitations of the study included use of convenience sampling which occurred because not all patients agreed to participate and because surgical positions other than supine and prone were categorically excluded from the study. Bias may have been introduced into the study as a result of manufacturer recommendations for mattress overlay use directly against skin. Use of the overlay in this manner prevented the investigators from being blinded at the time of postoperative assessment whenever the overlay was used. An additional limitation is the lack of reliability and validity data available on the Hemphill scale. In a small percentage of instances, the same person completed pre- and postoperative assessments on the same patient.

As health care institutions are mandated to provide care at lower costs, additional studies of the interactive effects of patient risk factors when combined with bedding materials designed to maintain optimal skin integrity will be needed to assist in quantifying individual patient potential for pressure sore formation. Further research also is needed to examine the relationship between bedding materials and pressure sore formation in infants, children under 12 years, and patients undergoing cardiac surgery. In addition, replication of this study may be advisable as new products become available.

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