# A Comparative Study of an Alternating Air Mattress for the Prevention of Pressure Ulcers in Surgical Patients

Sharon A. Aronovitch, PhD, RN, CETN[1]
Maureen Wilber, RN, CNOR[1]
Sue Slezak, RN, CNOR[2]
Tanya Martin, RN, BSN[1]
Denise Utter, RN, BSN[1]

Abstract

Research indicates that 8.5% of all patients undergoing surgical procedures for more than 3 hours develop pressure ulcers. In some types of surgery, incidence rates in excess of 25% have been reported. An 11-month study was conducted on the safety and efficacy of an experimental alternating air device in comparison with a tertiary care facility's conventional practice. A series of 217 patients undergoing surgical procedures scheduled for a minimum of 3 hours were enrolled. No ulcers developed in the experimental group and 11 ulcers developed in seven patients in the control group (8.75% incidence rate). Of the 11 ulcers, one was Stage I, four were Stage II, and six were unstageable secondary to eschar. The difference between the groups is significant at the $P = 0.005$ level. Individuals who developed ulcers had a length of stay approximately 7 days longer than the hospital average for comparable patients who did not develop ulcers.

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At the time of this study, Dr. Aronovitch was the Director, ET Nursing Education, [1]Albany Medical Center, Albany, NY, and Sue Slezak, RN, CNOR, was a Clinical Specialist, [2]MicroPulse™, Portage, Mich.

Address correspondence to:

Sharon A. Aronovitch, PhD, RN, CETN
21 Leaf Road
Delmar, NY 12054

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## Introduction

Pressure ulcers are a pervasive problem in healthcare. The cost of the problem is large, both in terms of individual human suffering and financial expense to society. Each year, 2.4 million people develop pressure ulcers in the United States.[1] Approximately 1.6 million of these individuals develop ulcers in acute care settings and nearly 25% of these ulcers occur in patients undergoing surgeries of 3 hours and longer.[1] Pressure ulcers that occur in acute care facilities represent a cost to the US healthcare system of $2.2 billion to $3.6 billion annually, and ulcers in surgical patients add $750 million to $1.5 billion annually to US healthcare costs.[1]

The incidence of pressure ulcers in hospitalized surgical patients[1] ranges from 4% to 66%, depending on

the population studied.[2,3] Incidence rises steadily with increased age, and in the hospitalized elderly, the incidence may increase to 20% to 32%.[4] In a recent national study 8.5% of all patients undergoing surgeries of greater than 3 hours and more than 17% of patients undergoing vascular surgery developed pressure ulcers.[5] Skin breakdown is the most cited complication of positioning for surgery.[6]

## Operating Room Specific Factors

A review of the literature related to pressure ulcers and surgical patients was conducted to determine the relevance of conducting a research trial of an alternating pressure surface in the operating room (OR). The literature review focused on information that revealed a potential connection between the OR environment and development of pressure ulcers.

Pressure ulcers are localized areas of cellular necrosis that develop when soft tissue is compressed for protracted periods between a bony prominence and a firm surface. This is a situation that presents in the OR as a result of unrelieved pressure exacerbated by extrinsic and intrinsic factors that act to reduce tissue tolerance to pressure.

A number of studies have been conducted to determine which specific intrinsic factors are most important in ulcer development in the surgical patient. Scott et al[7] and Papantonio[8] identified poor nutrition, elderly status, sensory loss, chronicity, impaired mobility, decreased mentation, and incontinence as important factors in the development of ulcers in the surgical patient. Papantonio[8] also identified low serum albumin, hematocrit, weight, and body mass as risk factors. Lewicki et al[2] found that type and length of surgery, state of consciousness, steroid use, multiple comorbid conditions, and a depression in hemoglobin, hematocrit, protein, and albumin contributed significantly to pressure ulcer development in the immediate postoperative period in elderly patients. Research by Lewicki also supports Marchette's assertion that decreased serum hemoglobin, hematocrit, and albumin levels contribute to the development of intraoperative pressure ulcers.[2,9] Many anesthetic agents interrupt the protective muscular mechanism by creating alterations in the vascular status. This biophysical action also alters blood pressure, tissue perfusion, responses to pressure and pain, and the exchange of oxygen and carbon dioxide.[6] A diastolic blood pressure of less than 60 mm Hg also has been associated with the development of pressure ulcers.[2,10] Most individuals undergoing surgery suffer from one or more of the above risk factors; therefore, placing most surgical patients at risk.

Extrinsic factors that contribute to pressure ulcer development include pressure, shear (ie, parallel force when the OR table is in side tilt), friction, and heat.[6,7,10] Sanada et al[11] studied the correlation between blood flow and pressure ulcer development during surgery. They found that the severity of tissue damage increased when blood flow decreased. The decrease in blood flow was due to the combined effects of pressure and shear. In addition, increasing temperature increases metabolic demand, magnifying the effect of decreased blood flow.

Skin breakdown of the heels, sacrum, and elbows is the most cited complication of positioning for surgery.[6] Long periods of immobility preoperatively and postoperatively in elderly patients has been cited as one contributor to pressure ulcer development in the immediate postoperative period.[3]

Increased skin temperature under the patient is one of the leading contributors to pressure ulcer development in surgical patients.[10,12,13] Air and water-warming systems are frequently used under patients during surgery. These devices increase heat metabolism, thereby increasing the need for cellular oxygen, nutrients, and the rate of byproduct removal.[12] Because this area is under pressure, vasodilatory responses are compromised and increased damage occurs.[14] Some studies indicate that the single greatest predictor of ulcer development is the use of a warming blanket underneath the patient.[10,12,13] This is consistent with the work of Kokate,[15] who demonstrated that tissue damage increases significantly as skin temperature increases, even when pressure and time remain constant.

## Pressure and Shear Reduction in the Operating Room

Pressure and shear are especially difficult to manage in surgical patients because of the requirements of surgery. Frequently, interface pressures are very high during surgery because of patient positioning, the additional weight of the OR staff leaning on the patient, and the loss of protection around the bony prominence due to a decrease in muscle tone from the use of anesthetic agents. Shear is also a major problem if patients are repositioned, even slightly, after anesthesia induction. Shearing creates lateral forces that are exerted as the surface of the skin is distended from the deep tissue, such as when the OR table is placed in a side tilt position. The displacement can lead to both ulceration and nerve damage in even relatively short surgeries.

Another source of pressure is the use of positioning devices, such as "bean bag" products. These products are a combination of silicone beads in a malleable casing that are placed beneath the patient to facilitate positioning; thereby, providing better visualization of the operative area for the surgeon. "Bean bags" are firm and can increase pressure over bony prominences, especially if the patient is repositioned even minimally after deflation of the "bean bag." Much controversy exists as to whether or not positioning devices relieve pressure as is advertised by the manufacturers. To date, no literature or research exists to support these claims.

Conventional OR table pads are 1-inch to 2-inch foam covered with a thick black conductive laminated fabric.[7] This pad is relatively hard and provides little if any pressure reduction. Some newer OR table pads are made of multidensity foam or a foam/gel combination with a flexible conductive laminated vinyl fiber. The most common types of pressure reductive pads used on the OR table are foam/gel (Akros®, Lumex Medical Products, Inc., Bayshore, NY) and a gel pad (Action® Pad, Action Products, Inc., Hagerstown, Md). A study on the effectiveness of three types of OR mattresses (a standard 2-inch foam OR mattress covered with vinyl, foam/gel, and gel pads) reported skin changes, including pressure ulcers, with all products.[16] The gel pad performed significantly better than the standard OR mattress pad in the prevention of pressure ulcers, particularly if the surgery was greater than 2.5 hours.[16]

The differences between mean tissue interface surfaces beneath the scapula, heel, and sacrum using three layers of 2-inch convoluted foam and a foam-replacement mattress were evaluated by Blaylock et al.[17] The study sample consisted of 20 patients undergoing vascular surgery. No statistically significant differences were reported between interface pressures for the products tested. In addition, the pressures in the sacral area were above 35 mm Hg on both devices.

Fredericks et al[18] evaluated OR mattress surfaces for skin vascular reactions using healthy subjects. Thermography, a noninvasive method of assessing regional blood flow, was used to gauge reactive hyperemia (increased blood perfusion in response to pressure) by measuring changes in the skin temperature. A standard 2-inch OR pad, a 0.75-inch gel pad, and a dynamic OR pad (MicroPulse®, Portage, Mich) were compared by measuring reactive hyperemia in the sacral area over a 2-hour period. Both the gel and experimental pads were placed on top of the standard OR pad. The experimental surface was shown to be statistically better in the maintenance of blood flow when compared to both the gel pad and standard OR pad. No statistically significant difference was reported between either the standard OR pad or the gel OR pad.

A recent study by Mayrovitz[19] investigated the skin blood flow before and after downloading of pressure. The study compared the skin blood perfusion of the greater trocanter area using static (gel) and dynamic (MicroPulse®) surfaces of 20 elderly volunteers. Mayrovitz reported that the dynamic surface had significant progressive perfusion compared to the static surface suggesting a greater blood flow during loading.[19]

Turning patients for pressure and shear relief is not a practical alternative during most surgeries. Special support surfaces for weight distribution products and alternating pressure also face a number of unique difficulties. Surfaces that are conformal enough to provide even moderate pressure reduction risk creating patient movement as various pressures are applied to the patient through contact with the surgical team. To be effective in maintaining blood flow, these surfaces must maintain an interface pressure below normal function mean capillary pressure of approximately 17 mm Hg, and in some individuals, capillary occlusion occurs at less than 12 mm Hg.[14,20,21] Even without the constraints of surgery, these pressures cannot be maintained on any known weight distribution surface. Conformal surfaces also tend to increase the height of the patient off the table making surgery more difficult. Surfaces used during surgery must also be radiolucent and easy to clean. Any system that alternates pressure must not transfer motion to the patient. Consequently, finding surfaces that are effective at reducing the incidence of pressure ulcers in surgical patients is difficult.

## Purpose

The primary objectives of the study were to determine the efficacy and safety of the experimental system (study group), in comparison with conventional management (control group), for the prevention of pressure ulcers in the operative and postoperative settings.

## Methods

Conventional management was defined as the use of an Action® Pad (Action Products, Inc., Hagerstown, Md) in the OR on top of a standard OR pad, and a Pressure Guard II® hospital replacement mattress (Span-America Medical Systems, Inc., Spartanburg, SC) on the hospital bed. Experimental management consisted of using the MicroPulse® System (MicroPulse, Inc., Portage, Mich) both during and after surgery.

The experimental system is comprised of a thin multi-segmented pad with more than 2,500 small air-cells enclosed in a fluid-proof cover. The air-cells are arranged in rows so the patient is supported by 50% of the cells (the inflated cells) at any given time. When the cells are deflated, they are not in contact with the patient. With a cycle time of less than 5 minutes, the tissue over the deflated cells has an opportunity to reperfuse at frequent intervals.

The primary efficacy variable was the occurrence of a pressure ulcer at any time within 7 days of surgery. The secondary efficacy variables included the number, stage, appearance, and size of the ulcer(s) at each post-operative day.

## Study Design

This was a single-center, 7 day, comparative, parallel study conducted at a tertiary care facility between March 1997 and February 1998. The protocol and associated informed consent form were reviewed and approved by the Institutional Review Board (IRB). Completed case report forms (CRFs) were monitored on site, at regular intervals throughout the study period.

The decision to include the surgical specialties of cardiothoracic, ENT, urology, and vascular was made based on information obtained through the literature review and conferences with the OR nurse manager. These surgical specialties were selected because they are high-volume practices and the average length of time per patient in the OR is 4 hours, which met one of the study's primary criteria.

To be eligible for inclusion in the study, patients were required to be 18 years of age or older undergoing a scheduled surgery with general anesthesia for at least 4 hours (actual operative time of 3 hours or more). Patients were to be excluded from the study if they participated in a clinical trial within 30 days of the baseline visit or if they had a pressure ulcer at the baseline visit.

Patients were to be removed from the study if they requested to be discontinued, experienced an adverse event (whether or not device related) that precluded continued treatment, or if the investigator felt it was not in the best interest of the patient to continue in the study.

Before enrolling patients in the study, the participating nursing units, including the OR staff, were educated on the protocol and the study product. Patients were enrolled into the study upon signing the informed consent form. Prior to surgery, patients were assigned to either the study group or control group. Randomization was performed by week rather than by patient to decrease protocol error. Patients assigned to the study group were placed on the experimental device in the OR and on their hospital bed until discharge from the hospital or for a maximum of 7 days post-surgery. Patients assigned to the control group were placed on a gel pad on top of the standard OR pad on the operating table, and then on a hospital replacement mattress until discharge.

At the baseline visit and before surgery, all enrolled patients underwent a review of the medical-surgical history, current medication, smoking history, dermatological examination, and skin risk assessment. Operating room data were also collected, including OR temperature, position of patient, amount of fluid provided during surgery, medications, episodes of hypotension, and use of extracorporeal circulation. The time spent in postanesthesia care unit was also recorded. Patients were examined following surgery and daily for pressure ulcers, including number, stage (I-IV), size (area), location, and appearance. The definitions used for staging pressure ulcers were based on the recommendations of both the NPUAP and the Wound, Ostomy, and Continence Nurses Society (WOCN).[22]

Patients were assessed for their daily ambulatory status. A skin risk assessment was performed on days 1, 4, and 7 as well as on other days if a change in status was noted.

The skin risk assessment tool used in this study was the Modified Knoll Risk Assessment Tool (see Figure 1). Abruzzese developed the original tool, Modified Assessment of Decubitus Ulcer Potential Tool, in 1974.[23] This tool was selected for the following reasons:

1. The Modified Assessment of Decubitus Ulcer Potential Tool contains all potential contributing risk factors for alteration in skin integrity
2. The development of the tool was based on a hospitalized patient population
3. Interrater reliability of the Modified Assessment of Decubitus Ulcer Potential Tool (Modified Knoll Risk Assessment Tool) for use with an acutely ill patient population is .8662.[24]

The variables included in the assessment tool are general health status, mental status, activity, mobility, incontinence, nutritional intake, fluid intake, and predisposing disease. Each variable is scored on a 0 to 3 scale. Double weight is assigned to the variables of activity, mobility, and incontinence based on previous study findings by Abruzzese.[25] The highest attainable score is 33, with a score of 12 or higher indicating a greater risk for the development of alterations in skin integrity.

**Modified Knoll Risk Assessment Tool**

**General Health Status**

0 **Good**–Injury limited to one area, free of major health problems.
1 **Fair**–Major surgery, major health problems are controlled.
2 **Poor**–Chronic/serious health problem, predisposing disease
3 **Moribund**–Prognosis poor predicted, stay in the acute care area > 1 month. Death expected within 3 months.

**Mental Status**

0 **Alert**–Aware of time and place, communicates properly.
1 **Lethargic**–Responds only with stimulation (verbal, noise, etc.). Sleeps for long periods, sleeps most of the day and night.
2 **Semicomatose/confused**–Responds appropriately to painful stimulus only, does not cooperate in the relief of pressure.
3 **Comatose**–Does not respond appropriately to pain, under paralyzing agents.

**Activity**

0 **Ambulatory**–Walks freely without help.
1 **Needs help**–Needs assistance to walk/get out of bed, gets out of bed by standing and pivoting.
4 **Chairfast**–Cannot ambulate, confined to chair/wheelchair, total lift out of bed.
6 **Bedfast**–Cannot sit in chair, remains constantly in bed.

**Mobility**

0 **Full**–Can move all extremities at will.
1 **Limited**–Cannot voluntarily move all extremities, cast on arm/leg, pain with joint movement.
4 **Very limited**–Moves extremities only with assistance, severe pain with joint movement, paralysis of upper/lower extremities, turning frame/RotoRest® bed.
6 **Immobile**–Never voluntarily changes position, contractures prevent movement, paralysis of all extremities.

**Incontinence**

0 **None**–Has control of bladder/bowels, foley/condom in place.
1 **Occasional**–Loses bladder control at times, foley/condom intermittently in place, loses control of bowels but no diarrhea, ostomy/fistula with drainage protection.
4 **Usually**–No control of bladder without foley/condom, diarrhea less than every 4 hours, ostomy/drainage with intermittent protective drainage system.
6 **Total**–No control of bladder without foley/condom, diarrhea more than every 4 hours, ostomy/drainage without protective drainage system.

**Nutritional Intake**

0 **Good**–Serum albumin normal (3.5 to 5), weight gain in the absence of edema, no obesity/underweight.
1 **Fair**–Serum albumin between 3.0 to 3.5, no peripheral edema, overweight/underweight, constant weight.
2 **Poor**–Serum albumin between 2.5 to 3.0, losing weight slowly, in the absence of edema/dialysis, obese.
3 **None**–Serum albumin less than 2.5, losing weight rapidly, in the absence of edema/dialysis, increased weight with edema.

**Fluid Intake**

0 **Good**–Good skin turgor, skin warm and resilient, intake and output equal with no peripheral edema.
1 **Fair**–Skin dry and flaccid, output is greater than intake.
2 **Poor**–Lips parched and mouth dry, cracked and flaking skin, edema to dependent areas.
3 **None**–Generalized edema of body, weeping of fluid from the skin.

**Predisposing Disease**

0 **Absent**–Has no vascular disease, immune suppression, neuropathies, diabetes, anemias, paralysis, hypoxia, no contributing dermal ulcer formation.
1 **Slight**–Controlled diabetes, anemia, incipient vascular disease, incipient skin disease.
2 **Moderate**–Brittle diabetic, sepsis but no shock, immune suppression with no infections, $PO_2$ between 60 and 80, advanced vascular disease as manifested by absent pulses, or poor capillary refill, frequent unhealed areas of skin.
3 **Severe**–Uncontrolled diabetes/anemia, $PO_2 < 60$, shock, paralysis, immune suppression with infection, well advanced vascular disease as manifested by lack of sensation, unhealed areas of the skin, edema of the ankles and feet, necrotic toes or fingers, evidence of stasis ulcers.

**Figure 1.** Use this tool to assess the patient for risk of skin breakdown. Record the scores and total on the appropriate sheets.

## Results

Two independent research firms conducted statistical analyses. Both firms analyzed the data for statistical significance related to demographics and treatment groups in relation to the development of intraoperative pressure ulcers. Baseline characteristics and demographics were compared between the treatment groups using Fisher exact and chi-square tests for multiway tables (ie, sex, race, smoking status) as well as the two-sample *t* test for age, blood pressure, pulse, and respiration. Type of surgery was also compared between the treatment groups using the chi-square test. The total preoperative skin assessment score was compared between treatment groups using Mantel-Haenszel (chi-square) test with modified ridit score, which permits the response levels to be scored using ranks, similar to the Wilcoxon rank sum test. All statistical tests were two-tailed and performed at the 0.05 level of significance.

A total of 234 patients signed informed consent forms resulting in a total of 217 patients assigned to be treated with either the experimental system (study group, n = 112) or conventional management (control group, n = 105). The 17 patients dropped from the study did not meet the inclusion criteria of OR time of 3 or more hours, had cancelled surgeries, or were discharged home before postoperative day 4. There were no significant differences between the groups with respect to sex, age, race, weight, height, or smoking classification (see Table 1).

The baseline skin risk assessment score for both groups was less than 4 with the range being 0 to 13. Baseline history for both groups was similar in ranking by percent for the diagnosis of cardiovascular disease and chronic illness affecting pressure ulcer formation. The study group had a higher percentage of patients with pulmonary disease, and the control group had a higher percentage of patients with cardiovascular disease (see Table 2).

Vascular surgeries were performed 44.7% of the time in the study group and 73.3% of the time in the control group. Vascular surgery procedures performed during this study were abdominal aortic aneurysm (13.4%, study group; 20%, control group), aortobifemoral bypass (3.6%, study group; 13.3%, control group), and insitu bypass (27.7%, study group; 40%, control group). This was followed in both groups by urological procedures (ie, nephrectomy, radical cystectomy with either continent or incontinent urinary diversion), head and neck surgery, and cardiothoracic

**Table 1**
**Age and Sex of Enrolled Patients***

| | Study Group (n = 112) | Control Group (n = 105) |
|---|---|---|
| **Sex** | | |
| Male | 79 (71.8%) | 77 (74%) |
| Female | 31 (28.2%) | 27 (26%) |
| **Age (years)** | 63.5 ± 11.9 | 64.7 ± 11.8 |
| < 50 | 12.7% | 16.3% |
| 50 – 60 | 21.8% | 17.3% |
| 61 – 70 | 37.3% | 27.9% |
| > 70 | 28.2% | 38.5% |
| **Race** | | |
| Caucasian | 95.5% | 92% |
| Black | 3.6% | 7% |
| Hispanic | 0 | 1% |
| Other | 0.9% | 0 |
| **Weight (pounds)** | | |
| Mean ± SD | 178.7 ± 40.35 | 168.1 ± 39.79 |
| **Height (inches)** | | |
| Mean ± SD | 66.23 ± 17.51 | 68.12 ± 4.248 |
| **Smoking status** | | |
| Smoker | 25 (23.8%) | 31 (30.4%) |
| Never smoked | 21 (20.0%) | 18 (17.6%) |
| Ex-smoker | 59 (56.2%) | 53 (52.0%) |

*All data not available for all patients.
$P = 0.05$, two-tailed.

**Table 2**
**Medical History***

| | Study Group (n = 112) | Control Group (n = 105) |
|---|---|---|
| **Cardiovascular disease** | 62.4% (n = 68) | 76% (n = 79) |
| **Chronic illness affecting pressure ulcer formation** | 31.8% (n = 35) | 44.2% (n = 46) |
| **Renal disease** | 21.1% (n = 23) | 18.8% (n = 19) |
| **Pulmonary disease** | 23.1% (n = 25) | 17.6% (n = 18) |
| **Bleeding problems** | 7.4% (n = 8) | 2.9% (n = 3) |
| **Previous pressure ulcer** | 2.7% (n = 3) | 8.9% (n = 9) |

*All data not available for all patients
$P = 0.05$, two-tailed.

procedures (see Table 3). Length of surgery for both groups averaged 5 hours with a range of less than 3 hours to more than 6 hours (see Table 4). The mean number of hours for the study group was 4:56 + 1:55 (SD) and 5:00 + 2:00 (SD) for the control group.

Seven patients (8.75%) in the control group developed a total of 11 pressure ulcers (see Table 5). One patient had three ulcers, two patients had two ulcers, and four patients had one ulcer. There were no reported Stage III or IV pressure ulcers, though six of the pressure ulcers were unstageable secondary to eschar. The difference in ulcer rate between the two groups was statistically significant ($P < 0.005$). One patient in the experimental study group developed an ulcer because of a piece of gel pad attached to the patient's upper right back. However, this was not considered to be related to the study device.

Statistical analysis demonstrated that for those patients who developed pressure ulcers in the control group compared to the study group, there was statistical significance for vascular surgery ($P = 0.02$), previous history of pressure ulcer ($P = 0.02$), and age ($P = 0.03$). Additional data analysis showed that by controlling for these factors there was still a significant difference in the development of pressure ulcers in the control group compared to the study group ($P = 0.04$).

An analysis was performed using only the vascular surgery patients. After controlling for age and baseline skin risk assessment, a chi-square analysis of type of device was conducted. This demonstrated a statistical significance associated between the device and the presence of pressure ulcers ($P = 0.023$).

Of the eight patients who developed ulcers (including the study patient), six had a length of stay longer than average for their specific diagnosis. The average length of stay for the group developing ulcers was 14 days, which was 6.7 days longer than the hospital's average of 7.3 days for this Diagnosis Related Group (DRG) mix. This represents an increase in length of stay of 92% in patients who developed ulcers. The total cost to care for the 8 patients with ulcers totaled $184,000. Total Medicare reimbursement for this mix of patients was $120,000. The cost to treat these patients if they had not developed ulcers is not known, but this indicates that the cost to treat patients who develop ulcers exceeds current reimbursement levels in many cases.

## Discussion

Limitations to this study are few. The primary impact was the limited type of surgeries that could be included in the study. This occurred because of

**Table 3**
**Percentage of Surgical Procedures***

| | Study Group (n = 112) | Control Group (n = 105) |
|---|---|---|
| **Abdominal aortic aneurysm** | 44.7% | 73.3% |
| **Urology** | 36.6% | 20.0% |
| **Insitu bypass** | 27.7% | 40.0% |
| **Head and neck** | 13.4% | 4.8% |
| **Aortobifemoral bypass** | 3.6% | 13.3% |
| **Cardiothoracic** | 1.8% | 0.0% |

*All data not available for all patients
$P = 0.05$, two-tailed.

**Table 4**
**Surgical Time in Hours**

| | Study Group (n = 112) | Control Group (n = 105) |
|---|---|---|
| < 3 | 9 | 12 |
| 3 – 3.99 | 20 | 12 |
| 4 – 4.99 | 33 | 21 |
| 5 – 6 | 28 | 36 |
| > 6 | 19 | 19 |

**Table 5**
**Characteristics of Patients with Intraoperatively Acquired Pressure Ulcers**

| Patient ID # | Race | Sex | Skin Risk Score | Ulcer Location | Stage | Type of Surgery | OR Time (hours) |
|---|---|---|---|---|---|---|---|
| 005 | White | F | 5 | Sacrum, right and left posterior thigh | U* | Abdominal aortic aneurysm | 5.25 |
| 018 | White | M | 5 | Right and left heel | II | Aortobifemoral bypass | 5.50 |
| 039 | White | M | 6 | Sacrum | II | Abdominal aortic aneurysm | 5.00 |
| 045 | White | M | 4 | Sacrum | U | Aortobifemoral bypass | 5.25 |
| 089 | White | M | 0 | Gluteal fold | I | Abdominal aortic aneurysm | 5.00 |
| 117 | White | M | 3 | Perianal | II | Aortobifemoral bypass | 3.75 |
| 143 | White | F | 7 | Perianal, left heel | U | Insitu bypass | 4.00 |

*U is unstageable secondary to eschar

the need for a positioning device ("bean bag") for some surgical procedures (ie, retroperitoneal abdominal aortic aneurysm repair), thereby limiting the patient pool to surgical procedures not requiring a positioning device. The study found that placing the positioning device beneath the experimental device was not acceptable to the surgeons because the width of the device was too wide to allow the surgeons comfortable accessibility to the operative site.

Another limitation was the small numbers of patients that were in the surgical groups for cardiothoracic and head and neck surgeries. The small population size cannot be used (on its own) to determine if there was a positive impact of the experimental device in preventing pressure ulcers for these two surgical groups.

The use of an alternating pressure system that has cells smaller than the smallest bony prominence appears to be effective in eliminating intraoperative pressure ulcers at this tertiary care facility. Even after adjusting for all known differences between the study and control groups, the experimental product was shown to be significantly more effective from both a clinical and statistical perspective when used in surgical patients both during and immediately following long surgical procedures. The surface was used without any adverse events during or after surgery, it caused no patient movement, and created no known infection control problems. It appears that using the experimental surface to prevent the devel-

opment of pressure ulcers may allow hospitals to reduce costs and lengths of stay while improving patient care.

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