Randomized Controlled Trial to Determine the Safety and Efficacy of a Multi-Cell Pulsating Dynamic Mattress System in the Prevention of Pressure Ulcers in Patients Undergoing Cardiovascular Surgery

James A. Russell, MD[1] and Samuel L. Lichtenstein, MD[2]

ABSTRACT

The purpose of this study was to determine the efficacy and safety of a multi cell pulsating dynamic mattress system in comparison with conventional management for the prevention of pressure ulcers in the operative and postoperative period in patients having cardiovascular surgery. The study was a single center, prospective, randomized, controlled trial. Patients who were having cardiovascular surgery for a duration of at least 4 hours were randomly assigned, prior to surgery, to a dynamic mattress system or conventional management. Risk assessments were initiated in the operating room and continued for 7 days postoperatively. Patients were assessed daily using standardized nursing scores. The results of 2 [illegible] days 198 patients in the dynamic pressure system group and 198 in the conventional management group. [illegible] baseline. A strong trend of decreased pressure ulcers [illegible] the dynamic pressure system group [illegible] conventional management group [illegible]. The evidence clearly [illegible] that a multi cell pulsating dynamic mattress system [illegible] mitigates risks for and decreases incidence of pressure ulcers in patients who undergo cardiovascular surgery.

Ostomy/Wound Management 2000; 46(2): 46–55

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.[1,2] These ulcers are caused by unrelieved pressure exacerbated by extrinsic and intrinsic factors that act to reduce tissue tolerance to pressure. Extrinsic factors that increase tissue susceptibility to external pressure include shear, friction, temperature, and moisture. Intrinsic factors include malnutrition, impaired mobility, advanced age, decreased mental status, incontinence, infection, and impaired sensory perception. In critically ill and cardiovascular surgery patients, decreased blood pressure and decreased skin blood flow also contribute to the development of pressure ulcers.[1,2]

More than 1.6 million hospitalized patients develop pressure ulcers each year. The incidence of pressure ulcers in hospitalized surgical patients ranges from 12% to 66%.[3,4] Incidence rises steadily with increased age. In the hospitalized elderly, the incidence may increase to 20% to 32%.[5,6] In a study done in Glasgow, England,[7] 71% of patients with pressure ulcers were 70 or older.

Complications of pressure ulcers include osteomyelitis and sepsis, with the mortality rate of sepsis approaching

From the [1]Department of Medicine, St. Paul's Hospital, and the [2]Department of Surgery, University of British Columbia, Vancouver, British Columbia, Canada. Address correspondence to: Dr. James A. Russell, Department of Medicine, St. Paul's Hospital, 1081 Burrard Street, Vancouver, British Columbia, V6Z 1Y6. *This study was funded by an operating grant from MicroPulse Inc., Portage, Michigan.*

50%.[8-10] Approximately 60,000 people die each year from complications of pressure ulcers.[11]

The exact incidence and prevalence of pressure ulcers in patients who undergo cardiovascular surgery is unknown despite well-defined pathophysiology and risk factors.[12-17] The National Perioperative Pressure Ulcer Prevalence study of U.S. hospitals in 1997 found that about 7% of patients who had undergone cardiovascular surgery developed pressure ulcers within 4 days of surgery.[18] Papantonio et al[19] found sacral pressure ulcers in 27% of cardiac surgical patients. Increased age, diabetes, and transfer from another hospital increased the risk of sacral pressure ulcers after cardiac surgery. To date, no prospective, randomized, controlled trials have been published on interventions (such as pressure-reducing devices) to prevent pressure ulcers in patients who undergo cardiovascular surgery.

A new patient support surface designed to prevent and treat pressure ulcers has potential for this patient population. The product is comprised of a thin pad with more than 2,500 small air cells enclosed in a fluid-proof cover. The air cells are arranged in rows so that 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 objective of this prospective, randomized, controlled trial was to compare the efficacy and safety of the multi-cell pulsating dynamic mattress system (MicroPulse Inc., Portage, Mich.) with conventional management in the prevention of pressure ulcers in the operative and postoperative settings in patients undergoing cardiovascular surgery. Conventional management was defined as the use of a gel pad (Action Pad®, Action Products, Inc.) in the operating room and a standard hospital mattress on the hospital bed. The standard hospital mattress in the critical care recovery unit was the Hill-Rom Centra with 6-inch foam overlay. The standard hospital mattress in the cardiac ward was the Hill-Rom Century with 4-inch foam overlay. The primary efficacy variable was the occurrence of pressure ulcers at any time within 7 days of surgery. The secondary efficacy variables included the number, stage, appearance, and size of ulcer(s) post-surgery.

Methods and Study Design

This was a single-center, randomized, controlled trial of a multi-cell pulsating dynamic mattress system versus conventional management for the prevention of pressure ulcers in patients who have cardiovascular surgery. The study was reviewed and approved by the Ethics Committees of St. Paul's Hospital and the University of British Columbia in Vancouver, British Columbia, Canada.

Patients were enrolled in the study after they signed the informed consent form. Before surgery, patients were randomly assigned to either the multi-cell pulsating dynamic mattress system or conventional management. Randomization was done blindly by using a sealed opaque envelope that contained the randomization information (ie, multi-cell pulsating dynamic mattress system vs. conventional management). Patients assigned to the multi-cell pulsating dynamic mattress system were placed on the system in the operating room and in their hospital room until discharge from the hospital or for a maxi-

Ostomy/Wound Management 2000;46(2):46–55

KEY POINTS

- A randomized, controlled clinical study was conducted to evaluate the efficacy of a pulsating dynamic mattress system in the prevention of pressure ulcers in patients undergoing cardiovascular surgery.
- During, and after surgery, patients in the treatment group were placed on the dynamic mattress system. Patients in the control group were placed on a gel pad during surgery, and on a standard hospital mattress (4- or 6-inch foam overlay) following surgery.
- In the treatment group, two of 98 patients (2.2%) developed a Stage II ulcer. In the control group, 7 of 100 patients (7%) developed 10 ulcers (2 Stage I, 5 Stage II, and 3 Stage III). Without controlling for other risk factors, this difference was not statistically significant.
- A 5% reduction in pressure ulcer incidence, while not statistically significant in this sample size, may have important clinical implications. The results also confirm trends observed by others using different types of "non-foam" support surfaces.

TABLE 1
PRESSURE ULCER SCORING SYSTEM

Stage I	Nonblanchable erythema of intact skin
Stage II	Partial-thickness skin loss involving epidermis, dermis, or both
Stage III	Full-thickness skin loss involving damage or necrosis of subcutaneous tissue that may extend down to, but not through, underlying fascia
Stage IV	Full-thickness skin loss with extensive destruction, tissue necrosis, or damage to muscle, bone, or supporting structures

mum of 7 days post-surgery. Patients assigned to the conventional management were placed on a gel pad on the operating table and then on a standard hospital mattress on the hospital bed until discharge.

Patient Selection

To be eligible for inclusion in the study, patients had to be 18 years of age or older and be scheduled for cardiovascular surgery with general anesthesia for at least 4 hours with an actual operative time of 3 hours or more. Patients were excluded if they had a pressure ulcer at the baseline visit. Additionally, patients were to be discontinued from the study if they so requested, had an adverse event that precluded continued treatment, or if the investigator felt it was not in the best interest of the patient to continue in the study.

Patients 1, 4, and 175 were randomized to the multi-cell pulsating dynamic mattress system. However, due to a change in the operating room schedule, each patient was placed on conventional treatment. For all analyses, these patients were assigned to the conventional management group.

Patient 62 was randomized to the multi-cell pulsating dynamic mattress system, but the family requested that the patient be removed from the study due to postoperative complications not related to the study device. The patient had no ulcer on the day of discontinuation (day 3). Patient 55 was randomized to conventional treatment, but was discontinued from the study on day 1 post-surgery due to cardiac arrest. This patient also had no ulcer on the day of discontinuation. These patients were included in the efficacy analysis.

Measurements and Evaluation

At the baseline visit before surgery, all patients underwent a medical evaluation including current medication, smoking history, physical examination, dermatological examination, and skin risk assessment. Operating room temperature, position of patient, amount of fluid intake during surgery, medications, episodes of hypotension, and duration of extracorporeal circulation during surgery were recorded. Patients were examined immediately post-surgery for pressure ulcers, including number, stage (1 to IV), size (area), location, and appearance. Patients were assessed daily for ambulatory status and presence of pressure ulcers. A skin risk assessment was performed on days 1, 4, and 7 and on other days if a change in status was noted. Adverse events and concomitant medications were recorded daily.

Pressure ulcers were defined and staged using the National Pressure Ulcer Advisory Panel scoring system.[20] The score ranges from zero (no ulcer) to IV (full-thickness ulcer to bone) as shown in Table 1. A modified risk assessment scale (see Table 2) was used to evaluate pressure ulcer risk.

Statistical Analysis

Baseline characteristics and safety were evaluated for all randomized patients (ie, intent-to-treat sample). Baseline characteristics and demographics were compared between treatment groups using Fisher's exact or Chi-square test for binary variables and the two-sample unpaired *t*-test for continuous variables. Total pre-operative skin assessment was compared between treatment groups using Mantel-Haenszel test with modified ridit score. The Mantel-Haenszel test is similar to the Chi square and tests for differences in proportions between groups to evaluate pre-operative skin assessment scores. The intent-to-treat sample included all patients who signed consent forms and who were placed either on a multi-cell pulsating dynamic mattress system or on a conventional mattress and had at least 1 day of observation post-surgery. An evaluable sample of patients was defined as patients who signed consent forms, had a surgery length of at least 3 hours, and had a minimum of 3 days of observation post-surgery. Two analyses were done for efficacy. One analysis included the intent-to-treat sample (multi-cell pulsating dynamic mattress system, n = 89; conventional management, n = 96) and the other analysis included only the evaluable patients sample.

The primary outcome measure for assessing efficacy was the proportion of patients who developed a pressure ulcer by day 7 post-surgery and was compared between the treatment groups using Fisher's exact test. All statistical tests were two-tailed and performed at the 0.05 level of significance.

TABLE 2
MODIFIED KNIGHT RISK ASSESSMENT SCALE

1. 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/expected, stay in the acute care >1 month. Death expected within 3 months.

2. Mental Status

0 Alert – Aware of time and place, communicates properly.
1 Lethargic – Responds only with stimulation (verbal, noises, 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, or is receiving paralyzing drugs.

3. 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.

4. 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.

5. 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 more 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.

6. Nutritional Intake

0 Good – Serum albumin normal (35 - 50 g/L), weight gain in the absence of edema, no obesity/underweight.
1 Fair – Serum albumin between 30 - 35 g/L, no peripheral edema, overweight/underweight, constant weight.
2 Poor – Serum albumin between 25 - 30 g/L, losing weight slowly, in the absence of edema/dialysis, obese.
3 None – Serum albumin less than 25 g/L, losing weight rapidly, in the absence of edema/dialysis, increased weight with edema.

7. 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 ski.n

8. Predisposing Disease

0 Absent – Has no vascular disease, immune suppression, neuropathies, diabetes, anemias, paralysis, hypoxia, no contributing dermal ulcer formation.
1 Slight – Controlled diabetic, 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 diabetic/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 ulcer.

TABLE 3
DEMOGRAPHICS AND BASELINE CHARACTERISTICS OF PATIENTS WHO HAD CARDIOVASCULAR SURGERY

		Multi-Cell Pulsating Dynamic Mattress System	Conventional Management
		n (%)	n (%)
Gender	Male	75 (76.5%)	75 (75%)
	Female	23 (23.5%)	25 (25%)
Age*		65.2 ± 10.9	65.2 ± 10.6
	< 50 years (n)	(10)	(8)
	50–60 (n)	(20)	(20)
	61–70 (n)	(30)	(36)
	> 70 (n)	(36)	(36)
Weight (kg)		79.1 ± 16.0	80.5 ± 15.0
Height (cm)		169 ± 9	170 ± 9
Vital Signs	Systolic BP (mmHg)	125 ± 21	126 ± 20
	Diastolic BP (mmHg)	70 ± 10	71 ± 12
	Pulse (beats/min)	68 ± 13	65 ± 12
	Respiration	18 ± 2	18 ± 1
		n (%)	n (%)
Race	Caucasian	93 (94.9%)	87 (87.0%)
	African-American	—	1 (1.0%)
	Asian	2 (2.0%)	2 (2.0%)
	Hispanic	—	3 (3.0%)
	Other	3 (3.1%)	7 (7.0%)
Smoking history		n (%)	n (%)
	Smoker	17 (17.5%)	15 (15.2%)
	Ex-smoker	44 (45.4%)	51 (51.5%)
	Never smoked	36 (37.1%)	33 (33.3%)

* All results are reported as mean ± standard deviation

Results

A total of 200 patients signed informed consent forms and 198 patients were assigned to either the multi-cell pulsating dynamic mattress system (n = 98) or conventional management (n = 100). There were no significant differences between the groups with respect to gender, age, weight, height, vital signs, race, or smoking history. Table 3 shows demographic and baseline characteristics.

No differences existed in medical illnesses or skin risk-assessment scores between groups. Table 4 shows the baseline medical illnesses and skin assessment. The duration of surgery is shown in Table 5. No differences were observed between the treatment groups.

By day 7, two multi-cell pulsating dynamic mattress system patients developed ulcers and seven conventional management patients developed ulcers. The difference in ulcer rate between the two groups was not statistically significant ($P = 0.170$ for the intent-to-treat population and $P = 0.172$ for the evaluable population). However, patient 15, who was randomized to the multi-cell pulsating dynamic mattress system, spent several hours sitting on a chair without the multi-cell pulsating dynamic mattress system on post-op day 4 and day 5. The patient developed a pressure ulcer on post-op day 5. If this ulcer is excluded from the analysis, the P value is 0.065 for the intent-to-treat population and 0.066 for the evaluable population. This suggests a strong trend of decreased pressure ulcers in the multi-cell pulsating dynamic mattress system group. Table 6 shows the incidence of pressure ulcers in each group.

In the multi-cell pulsating dynamic mattress system group, each patient developed one Stage II ulcer (see Table 7). In the conventional management group, seven patients developed 10 ulcers. Five of these patients had one ulcer each, one patient had two ulcers, and one patient had three ulcers. Of these ulcers, two were Stage I, five were Stage II, and three were Stage III. The three Stage III ulcers occurred within 7 days postoperatively.

Approximately one half of all patients in each group reported adverse events, with no differences between groups reported. All adverse events were related to the patient's condition; none were related to the multi-cell pulsating dynamic mattress system or conventional management support system.

Discussion

This prospective, randomized, controlled trial showed that the multi-cell pulsating dynamic mattress system decreased the incidence of pressure ulcers in patients who had cardiovascular surgery. The incidence of pressure ulcers was decreased from 7% in the conventional management group to 2% in the multi-cell pulsating dynamic mattress system group, which is about a 75% relative risk reduction.

The incidence of pressure ulcers in the conventional management group (7%) was similar to the incidence of pressure ulcers in the National Perioperative Pressure Ulcer Prevalence Study (7%),[18,21] suggesting

TABLE 4
BASELINE MEDICAL ILLNESSES AND SKIN RISK ASSESSMENT IN PATIENTS WHO HAD CARDIOVASCULAR SURGERY

	Multi-Cell Pulsating Dynamic Mattress System	Conventional Management
Baseline Skin Risk Assessment Score		
Mean ± standard deviation	3.6 ± 1	3.8 ± 1
Range	1–8	1–7
Baseline Disease History	n (%)	n (%)
Previous ulcer formation	0	1 (1)
Cardiovascular disease	98 (100)	100 (100)
Renal disease	8 (8.2)	8 (8)
Pulmonary disease	7 (7.1)	12 (12)
Bleeding problems of easy bruising	0	1 (1)
Chronic illness affecting pressure ulcer formation	26 (26.5)	20 (20)
Other medical problems	78 (79.6)	83 (83)
Allergies	27 (27.6)	28 (28)

TABLE 5
DURATION OF SURGERY IN PATIENTS WHO HAD CARDIOVASCULAR SURGERY

	Multi-Cell Pulsating Dynamic Mattress System	Conventional Management
Duration	n (%)	n (%)
< 3 hours	8 (8.2)	4 (4)
3–3.99	40 (40.8)	34 (34)
4–4.99	27 (27.6)	40 (40)
5–6	17 (17.4)	16 (16)
> 6	6 (6.1)	6 (6)
Length of surgery	**4.1 ± 1.0**	**4.2 ± 1.1**

that our sample of patients having cardiovascular surgery is similar to the sample of patients in the National Perioperative Pressure Ulcer Prevalence Study. Furthermore, the type of surgery, duration of surgery, and outcomes were representative of patients having major cardiovascular surgery that requires cardiopulmonary bypass. Thus, the strong trend of decreased frequency of pressure ulcers in the dynamic mattress system group was demonstrated in a sample of patients representative of patients having cardiovascular surgery. Therefore, the results of this study are applicable to this patient population.

A recent report was published of a prospective randomized trial of the multi-cell pulsating dynamic mattress system versus conventional management in patients having surgery for more than 3 hours, many of whom underwent vascular surgery.[22] This study also found that the multi-cell pulsating dynamic mattress system decreased the prevalence of pressure ulcers from 9% to 0%.[22]

Although the difference between the multi-cell pulsating dynamic mattress system and the conventional management group in the present study was not quite statistically significant, each of the ulcer patients treated with the multi-cell pulsating dynamic mattress system had only one ulcer, while seven patients in the conventional management group had a total of 10 ulcers. In addition, one patient in the conventional management group had one Stage III ulcer and one patient had two Stage III ulcers. Furthermore, the difference in outcomes has clinical significance because there was an approximately 75% reduction in relative risk of pressure ulcers.

A strong point of this study is that it was a prospective, randomized trial with blinded randomization. Additionally, the two experimental groups were well-matched at baseline in terms of skin risk assessment, medical illness, age, weight, and duration of surgery, all of which suggests both groups were at equal risk for developing pressure ulcers. The two experimental groups were well-matched because the study was double-blinded in the randomization process. Showing that the two groups were well-matched at baseline is important so that differences between the groups in outcome can be attributed to the intervention as opposed to differences in baseline risks for skin ulcer. Therefore, the difference in pressure ulcer outcomes between groups can be attributed to the multi-cell pulsating dynamic mattress system. Another strength of this study is that the patients were representative of major surgery patients who are at risk of developing pressure ulcers.

The design of our study reflects the hypothesis

TABLE 6
INCIDENCE AND STAGES OF PRESSURE ULCERS IN PATIENTS WHO HAD CARDIOVASCULAR SURGERY

	Multi-Cell Pulsating Dynamic Mattress System	Conventional Management
	n (%)	n (%)
Total number of patients with ulcer(s) %	2* (2.2)	7 (7)
Number of patients with 1 ulcer	2 (2.2)	5 (5)
Number of patients with 2 ulcers	0	1 (1)
Number of patients with 3 ulcers	0	1 (1)
Number of patients with more than 3 ulcers	0	0
Ulcer Stages		
Number of Stage I ulcers	0	2 (2)
Number of Stage II ulcers	2 (2.2)	5 (5)
Number of Stage III ulcers	0	3 (3)
Number of Stage IV ulcers	0	0

*One patient (patient 15) was on a multi-cell pulsating dynamic mattress system during surgery and post-op for 7 days, but spent several hours sitting on a chair without a multi-cell pulsating dynamic mattress system on post-op day 4 and day 5. The patient developed an ulcer on post-op day 5.

that the risk of pressure ulcer begins on the operating room table in surgical patients. During cardiovascular surgery, patients have a prolonged period of immobilization, a change in cardiac output to nonpulsatile flow, and possible periods of hypotension. These events increase the risk of pressure ulcer development. This study shows that the risk from these events can be mitigated by placing patients on the multi-cell pulsating dynamic mattress system intraoperatively and postoperatively.

Pressure ulcers are important problems for patients in surgical intensive care units[13,23] and postoperative surgical wards.[3–5,16] The role of the risks during surgery has only recently been recognized.[14–17] This study directly addressed this issue by beginning the intervention to reduce risk at the time of surgery. Preventing pressure ulcers by early risk reduction strategies likely results in *cost savings by avoiding the treatment of pressure ulcers* and their complications.[24]

In summary, the multi-cell pulsating dynamic mattress system is both safe and efficacious in reducing the incidence of pressure ulcers in patients undergoing major cardiovascular surgery of 3 hours duration or more. This system reduces the incidence of pressure ulcers by mitigating intraoperative and postoperative risks for pressure ulcers. Applying the multi-cell pulsating dynamic mattress system at the time of surgery suggests that early intervention is effective and infers that the genesis of pressure ulcers in cardiovascular surgical patients begins at the time of surgery.

Acknowledgements

The authors greatly appreciate the excellent work of Mr. Vince Dunlop, RN, who was the Research Associate of this study. Dr. Russell has been a consultant for MicroPulse, Inc. - OWM

References

1. Bennett L, Kavner D, Lee BK, Trainor FA. Shear vs. pressure as causative factors in skin blood flow occlusion. *Arch Phys Med Rehab.* 1979;60:309–314.
2. Ek AC, Lewis DH, Zetterquist H, Svensson PG. Skin blood flow in an area at risk for pressure sore. *Scand J Rehab Med.* 1984;16:85–89.
3. Allman RM. Pressure ulcer prevalence, incidence, risk factors and impact. *Clin Geriatr Med.* 1997;13:421–436.
4. Kemp MG, Keithley JK, Smith DW, et al. Factors that contribute to pressure sores in surgical patients. *Res Nurs Health.* 1990;13:293.
5. Stotts NA. Predicting pressure ulcer development in surgical patients. *Heart Lung.* 1988;17:641.
6. Norton D, McLaren R, Exton-Smith AN. Pressure sores. In: *Investigation of Nursing Problems in Hospital.* Edinberg: Churchill-Livingstone 1975;194–235.
7. Berbenel JC, Jordan MM, Nichol SM, et al. Incidence of pressure sores in The Glasgow Health Board area. *Lancet.* 1977;2:548.
8. Galpin JE, Chow A, Bayer AS, et al. Sepsis associated with pressure ulcers. *Am J Med.* 1976;61;346.
9. Sugarman B. Pressure sores and underlying bone infection. *Arch Intern Med.* 1987;143:553.

TABLE 7
DESCRIPTION OF THE PATIENTS WHO HAD PRESSURE ULCERS

PID	Race	Sex	Age	Location of ulcer	Stage† (I–IV)	Size (cm^2)	Surgery length (hours)	Skin Risk Assessment Score
Multi-cell Pulsating Dynamic Mattress System								
15*	Caucasian	F	75	Sacrum	II	4	3.3	4
80	Caucasian	F	78	Sacrum	II	1	4.7	8
Conventional Management								
2	Caucasian	M	64	Sacrum	I	2	4.3	2
11	Caucasian	M	77	Sacrum	I	1	4.2	6
40	Caucasian	M	63	Sacrum	II	4	4.2	4
52	Caucasian	M	73	Sacrum	II	1	4.3	4
87	Caucasian	F	79	Sacrum	II	6	5.2	4
175	Caucasian	M	68	Left heel	III	3	3.4	3
				Sacrum	II	8		
183	Caucasian	M	65	Sacrum	III	16	6	4
				Left trochanter	III	12		
				Right trochanter	II	4		

*Patient 15 was on a multi-cell pulsating dynamic mattress system during surgery and post-op for 7 days, but spent several hours sitting on a chair without a multi-cell pulsating dynamic mattress system on post-op day 4 and day 5. The patient developed an ulcer on post-op day 5.

†Staging system from the Agency for Healthcare Policy and Research 1994.

10. Bryan CS, Dew CE, Reynolds KL. Bacteremia associated with decubitus ulcers. *Arch Intern Med.* 1983;143:2093.
11. Thomas DR, Goode PS, Tarquine PH, Allman RM. Hospital-acquired pressure ulcers and risk of death. *J Am Geriatr Soc.* 1996;44:1435–1440.
12. Sanada H, Nagakawa T, Yamatmoto M, et al . The role of skin blood flow in pressure ulcer development during surgery. *Advances in Wound Care.* 1997;10:29–34.
13. Marchette L, Arnell I, Redick E. Skin ulcers in elderly surgical patients in critical care units. *Dimensions in Critical Care Nursing.* 1991;10:321–329.
14. Hoyman K, Gruber N. A case study of interdepartmental cooperation: operating room-acquired pressure ulcers. *J Nurs Care Qual.* 1992;Special Report:12–17.
15. Walsh JW. Post-op effects of OR positioning. *RN.* 1993;Feb:50–57.
16. Stewart TP, Mangano SJ. Burns or pressure ulcers in the surgical patient. *Decubitus.* 1998;1:36–40.
17. Kemp MG, Keithley JK, Smith DW, Morreale B. Factors that contribute to pressure sores in surgical patients. *Res Nurs Health.* 1990;13:293–301.
18. Aronovitch S. A comparative, randomized controlled study to determine safety and efficacy of preventative pressure ulcer systems: preliminary analysis. Presented at: First Annual Symposium on Operating Room Acquired Pressure Ulcers; March 8–9, 1998; Atlanta, Ga.
19. Papantonio CT, Wallop JM, Kolodnor KB. Sacral ulcers following cardiac surgery: incidence and risks. *Advances in Wound Care.* 1994;7:24–35.
20. Barczak CA, Barnett RI, Childs EJ, Bosley LM. Fourth National Pressure Ulcer prevalence study. *Advances in Wound Care.* 1997;10:18–26.
21. Aronovitch S. Intra-operatively acquired pressure ulcer prevalence: a national study. Presented at: First Annual Symposium on Operating Room Acquired Pressure Ulcers; March 8–9, 1998; Atlanta, Ga.
22. Aronovitch S. A comparative study of an alternating air mattress for the prevention of pressure ulcers in surgical patients. *Ostomy/Wound Management.* 1999;3:34–44.
23. Robnett MK. The incidence of skin breakdown in a surgical intensive care unit. *Journal of Nursing Quality Assurance.* 1986;1:77.
24. Beckrich K. An analysis of the cost of pressure ulcers in medical versus surgical patients. Presented at: First Annual Symposium on Operating Room Acquired Pressure Ulcers; March 8–9, 1998; Atlanta, Ga.