Preventing Pressure Ulcers: An Evaluation of Four Operating-Table Mattresses

Tom Defloor and Johan D. S. De Schuijmer

Pressure is a major factor in the development of pressure ulcers. This research focused on assessing the pressure-reducing effects of operating-table mattresses. Five mattresses were tested: a standard operating-table mattress, a foam mattress, a gel mattress, a visco-elastic polyether mattress, and a visco-elastic polyurethane mattress. Four intraoperative postures were evaluated: supine, lateral, fossa, and the Miles-Pauchet position. Interface pressure measurements were performed on 36 healthy volunteers. The foam mattress and the gel mattress seem to have little or no pressure-reducing effect; the polyurethane mattress and the polyether mattress reduce interface pressure significantly better ($p < .001$); but none of the mattresses reduce pressure sufficiently to prevent the occurrence of pressure ulcers.

A COMMON PROBLEM FOR SURGICAL PATIENTS is the development of pressure ulcers. A pressure ulcer is an area of localized damage to the skin and to the underlying tissue caused by pressure, shear, and/or friction (European Pressure Ulcer Advisory Panel, 1999). The higher the intensity of the pressure and shearing forces, and the longer the duration, the higher the risk for developing pressure ulcers. Individual susceptibility to pressure and shearing forces, the so-called "tissue tolerance," determines whether pressure ulcers develop (Defloor, 1999).

It has been reported that pressure ulcers develop in 5.5 to 32% of all hospitalized patients (Barczak, Barnett, Childs, & Bosley, 1997; Bours, Halfens, & De Winter, 1998; Harrison, Wells, Fisher, & Prince, 1996). The incidence of pressure ulcer formation on surgical units varies between 7 and 66% (Bridel, 1993a; Kemp, Keithley, Smith, & Morreale, 1990; Lyder et al., 1998; Tubman Papantonio, Wallop, & Kolodner, 1994).

The intraoperative period may be the time of highest risk for the hospitalized patient (Bridel, 1993b; Campbell, 1989). Injuries usually become visible during the postoperative stay in surgical or intensive care units. The ulcer may not be apparent on completion of surgery; 3 to 5 days may pass before there are visible signs of damage (Vermillion, 1990). Because there is often a delay before tissue damage is apparent, it, mistakenly, may not be attributed to the surgical procedure. Lesions thought to be accidental burns or injuries developed during surgery are sometimes nondiagnosed pressure ulcers (Gendron, 1980; Hoyman & Gruber, 1992). Small, painless pressure ulcer injuries frequently heal unnoticed postoperatively and are never observed or reported (Tubman Papantonio et al., 1994).

Factors specific to the intraoperative phase identified as contributing to pressure ulcer formation include weight, type of surgery, and use of a thermal blanket (Campbell, 1989); time on operating table, extracorporeal circulation, and age (Kemp et al., 1990); time on operating table longer than 2.5 hours, presence of vascular disease, and age over 40 years (Hoshowsky & Schramm, 1994).

Stotts (1988) studied 387 cardiovascular surgery or neurosurgery patients and found that patients who underwent cardiovascular surgery had a higher risk of developing a pressure ulcer. Scott (1998) confirmed higher incidence of pressure ulcers in vascular patients in comparison with abdominal, urologic, and orthopedic surgery patients.

Tubman Papantonio et al. (1994) examined the development of pressure ulcers in 136 cardiac surgery patients. Fourteen percent of the stage I ulcers (nonblanchable erythema) appeared in the

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first 18 hours postsurgery, whereas 63% of the ulcers that progressed to stage II or III (blistering or superficial pressure ulcers) first appeared within this time frame.

Pressure ulcers initially develop in muscle and subcutaneous tissues, progressing outward toward dermal and epidermal skin layers (Shea, 1975). Muscle is damaged first because pressure is the greatest over the bone. The pressure progressively decreases toward the periphery, creating a hammock effect (Staarink, 1995).

Campbell (1989) found that the postsurgical interface pressure—the pressure applied to the skin by the surface that is supporting it (Burman, 1994)—of patients on the operating table for more than 2.5 hours was 35% higher than pressure measurements during preanaesthetic induction. This suggests that interface pressure measurements using healthy volunteers provide a conservative picture of the pressures to which patients are exposed while undergoing surgery (Bridel, 1992). The interface pressure on patients lying on an operating table can be extremely high. Pressure readings of up to 260 mmHg have been reported (Neander & Birkenfeld, 1991). Leaning on or against the patient during an operation may also increase the risk of pressure ulcer development.

Perioperative pressure ulcers may be prevented by decreasing the intensity of pressure and shearing forces. McEwen (1996) stressed the importance of correctly positioning a patient on the operating table. Shearing force may be minimized by using technical aids and techniques. Correct application of safety straps, intended to maintain a patient in a certain position, may avoid increasing the pressure. Cheney (1993) reported the successful use of quilted heel protectors in the prevention of heel pressure ulcers during orthopedic surgery.

Sheepskins, which are also frequently used, have no pressure reducing qualities (Defloor & Grypdonck, in press). Tubman Papantonio et al. (1994) warned that artificial sheepskin pads may actually contribute to the development of pressure ulcers.

There are two levels of support surfaces: pressure reduction versus pressure relief (Colwell, 1997). The reported difference between the two is reflected by a capillary-closing pressure of 32 mmHg. Pressure-relief support surfaces reduce the interface pressure $<$32 mmHg, whereas pressure-reducing support surfaces do not. Krouskop, Garber, and Noble (1990) emphasized that no single threshold pressure can ensure tissue viability for every individual. The variability of individual medical and physical conditions makes it impossible to stipulate one universal ‘‘safe’’ interface pressure threshold (Burman, 1993). No support surface relieves pressure for each individual. The best compromise is to select support surfaces that reduce interface pressures to a minimum (Krouskop, Garber, & Noble, 1990).

Pressure-reduction devices may be classified as static or dynamic. Static devices are designed to provide dry flotation, while dynamic devices involve a pump or motor to provide constantly changing pressure points. On an operating table, static devices are preferable because they ensure stability during surgical procedures (Hoshowsky & Schramm, 1994); however, Aronovitch (1998) and Aronovitch, Utter, and Wilber (1998) conducted a trial with an alternating air pad system with 3,700 cells and reported no stability problems.

Several types of operating-table mattresses have been developed to reduce interface pressure. According to Hoshowsky and Schramm (1994), ideal characteristics for bedding used in the operating room are stability, firmness, pressure reduction, and even pressure distribution without ‘‘bottoming out’’—flattening or collapsing such that the patient is resting on the underlying surface, thus defeating the purpose of the mattress.

Nixon, McElvenny, Mason, Brown, and Bond (1998) found that the use of a gel pad reduced the probability of pressure ulcer development by half in comparison with the standard operating-table mattress. Hawkins (1997) investigated the pressure ulcer incidence in 361 cardiovascular patients using a standard operating-table mattress, an air-filled pad, and a foam pad. She found a statistically significant ($p = .003$) lower pressure ulcer incidence in the group of patients using a foam mattress ($<$1%) or an air-filled pad (0%) in comparison with the group of patients using a standard operating-table mattress (6.5%).

Campbell (1989) noticed that eliminating layers of cloth or material between the patients and the operating room table pad decreased sacral interface pressure readings.

PURPOSE OF INVESTIGATION

Because neither the position of the patient on the operating table nor the time span of surgery can be altered to prevent pressure ulcers, pressure reduction, using a special operating-table mattress, seems to be the most appropriate method for preventing pressure ulcers during the intraoperative period. According to Gendron (1980), air mattresses and water mattresses were not suited because of their instability and leakage problems. Several types of operating-table mattresses are available on the market. The degree to which these mattresses effectively reduce pressure is not clear. The pressure-reducing effect in different operation positions has not been investigated. This research focuses on the following question: What is the effect of operating-table mattress type and surgical position on interface pressures in healthy adults?

METHOD OF INVESTIGATION

Interface pressure measurements were conducted in a laboratory setting on 36 healthy volunteers lying in four intraoperative positions on five types of operating-table mattresses. A quasi-experimental design was used.

Operating-Table Mattresses

Five types of mattresses were tested: a standard hospital operating-table mattress (mattress, part of a Maquet operating table), a foam mattress, a gel mattress, a visco-elastic polyether foam mattress, and a visco-elastic polyurethane mattress (Table 1).

Positions

Four positions, in which patients are frequently placed during extensive (>2 hours) surgery, were evaluated (Figure 1).

In the supine position, the subject was lying on the back with arms stretched out next to the body and both legs stretched and parallel to each other.

In the lateral position, the subject was completely turned to one side, the angle between back and operating table was 90°. The upper leg was placed in front of the lower leg and was bent at the knee. The lower arm was stretched sideways to form a 90° angle with the body. The upper arm was stretched on top of the body.

In the fossa position, the head end of the operating table was raised to an 80° angle. The subject was sitting sideways on the edge of the operating table. The feet were put on a footrest. The subject was leaning backward and was supported in the back. The head and the shoulder were leaning against the operating table. The subject was sitting on an additional cushion consisting of the same material as the mattress. Because such a cushion was not available for the standard operating-table mattress, the interface pressure in this position was not measured for the standard operating-table mattress.

In the Miles-Pauchet position, the foot end of the table was replaced by leg supports. The subject's thigh line was positioned on the bottom edge of the table. The upper legs were horizontally positioned on the leg supports at the same height as the thorax. The lower legs were positioned slightly below the height of the upper legs.

Interface pressure measurement

The measurement system used was the Ergocheck® system (ABW, Hamburg, Germany). This system consists of a measuring mat containing 684

Table 1. Operating Table Mattresses

Type	Product Name	Distributor/ Producer	Thickness (cm)	Weight (kg)	Non-slip Underlay	Zipper	Seams
Gel	Action	Action, USA	1, 5	15	No, but very good adherence	—	— (welded at side)
Foam, 3 cm 45-50 g/m² and 3 cm 70-75 g/m²	—	University Hospital of Ghent, Belgium	6	2.3	No	—	Sides (middle)[a] 3 sides
Polyether visco-elastic foam	SAF	Sampli, Belgium	6	3.2	No	Sides (middle) noncovered[a]	Sides (middle)[a] 2 sides + 2 sides zipper
Polyurethane visco-elastic foam	Tempur-Pedic	Fagerdala, Sweden	7	6	Yes	Bottom (middle) Covered	Sides (bottom) 4 sides
Standard (foam)	—	—	4	2	No	—	Side (middle)[a] 3 sides

[a]Risk for hygiene because of possible seepage of blood, fluids, etc.

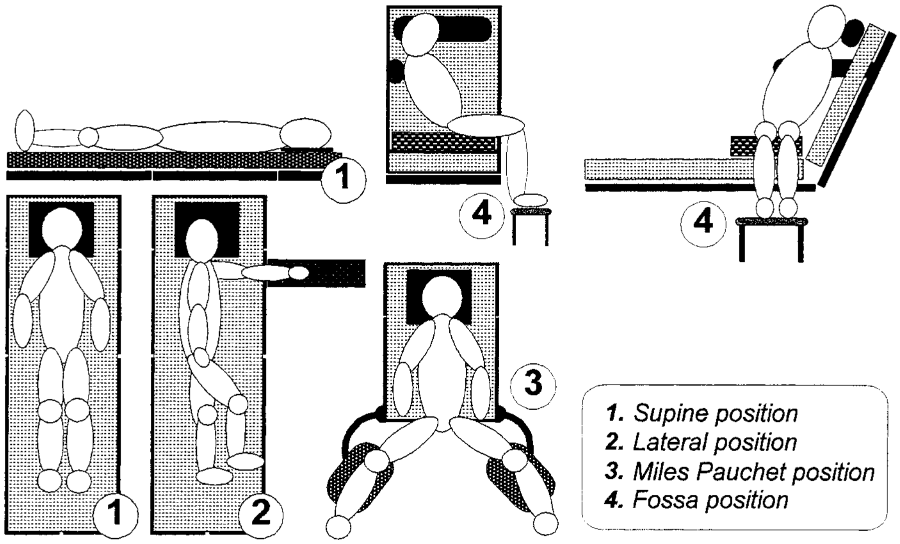

Figure 1. Intraoperative positions.

sensors, positioned at a distance of three cm. Each of these sensors has a diameter of 0.4 cm, is filled with air, and linked to a pressure transducer by means of a polyvinyl chloride (PVC) air tube. Pressure exerted on a sensor is accompanied by a displacement of air through the air channel. This displacement of air is converted into a digital signal by the pressure transducer. The signals of each separate sensor were registered on a computer system. The Ergocheck® allows not only measurement of the pressure on each sensor, but also measurement of the size of the whole contact surface. The measuring sheet is very flexible, so the influence on the pressure-reducing properties of the mattresses tested is minimal (Willems, 1995).

The system was standardized prior to every measurement and with every manipulation of the measuring mat. The reported measuring error is between 1.7 and 3.7% ± 2.5% on the entire measuring sheet (Defloor, 2000).

Interface pressure measurements in the supine position were done twice for each test subject. The test-retest reliability was high ($r = .99$; $p < .001$) (Figure 2).

Subjects

Interface pressure measurements were was taken for 36 healthy volunteers—24 women and 12 men, ages 23 to 56 years ($M = 37.5$ years, $SD = 9.99$ years). The average body weight was 72.9 kg ($SD = 16.6$ kg). The body mass index (BMI) varied between 18.3 and 42.6 kg/m^2 ($M = 25.1$ kg/m^2, $SD = 4.9$ kg/m^2). The normal BMI range is between 18.5 and 24.99 kg/m^2 (WHO, 1995).

Investigative procedure

Both the order of mattresses and of positions were randomized for every subject. After the calibration of the pressure sensors, the subject was requested to take her or his place on the first mattress in the first position. The measurement was performed after 1 minute of immobilization. Previous research showed that interface pressures remained unchanged if longer periods of immobilization were used. The same procedure was followed for each of the other positions. The measuring mat was recalibrated each time the mattress was changed (Defloor, 2000; Defloor & Grypdonck, in press).

After the measurements were taken, the results were entered in a computer and processed using the statistical program SPSS 7.5. The differences between the positions were checked by means of analysis of variance and Tukey tests. The level of significance used was $p = .5$.

RESULTS

The interface pressure in the supine position measured on a standard operating-table mattress was relatively high ($M = 49.2$ mmHg, $SD = 9.6$ mmHg). In a previous study using the same measuring system and protocol, the interface pressures

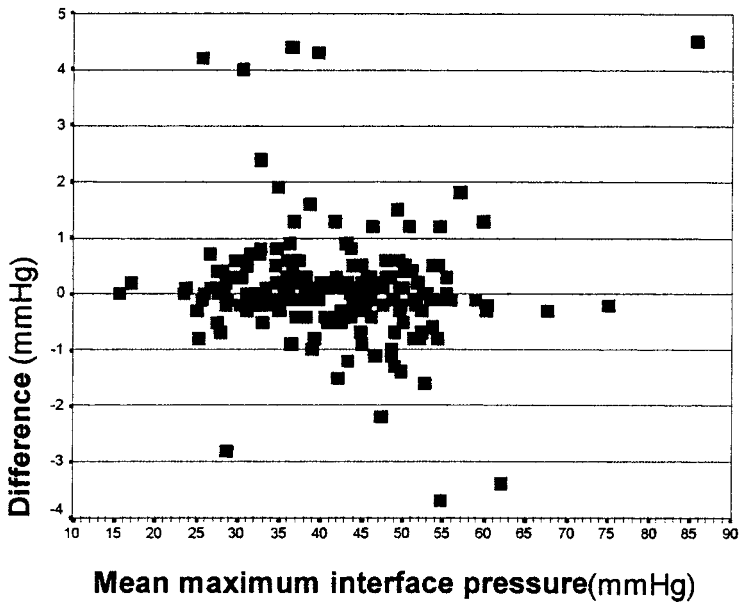

Figure 2. Maximum interface pressure (mean of both measurements) versus difference between both measurements (*n* = 36).

measured on a standard (not-pressure reducing) hospital mattress in the supine position (*M* = 39.5 mmHg, *SD* = 7.0 mmHg) and on a visco-elastic polyurethane foam hospital mattress (*M* = 27.7 mmHg, *SD* = 4.1 mmHg) were lower (Defloor, 2000).

The mean maximum interface pressure in supine position varied between 32 and 49.2 mmHg for all five mattresses (Table 2). In the other three positions, the interface pressure was higher than the interface pressure registered in the supine position and varied according to the mattress used (Figure 3).

In all positions, the interface pressure was higher on the standard operating-table mattress than on the other types of mattresses. The supine position was the only position in which there was no significant difference between the standard hospital mattress and the foam mattress (Table 3).

The polyurethane mattress had a significant lower interface pressure than the gel, foam, or standard operating-table mattresses. In the supine position, the polyurethane mattress reduced interface pressure by an average of 16.3 mmHg (*SD* = 7.7 mmHg), whereas the polyether mattress reduced the interface pressure by an average of 13.7 mmHg (*SD* = 11.7 mmHg) compared to the standard operating-table mattress. In the supine and fossa positions, the polyether mattress generated a lower interface pressure than the gel mattress, foam mattress, or standard mattress. In the fossa position, interface pressures were lower on a polyurethane mattress than on a polyether mattress, gel mattress, or foam mattress.

Table 2. Maximum Pressure (mmHg) on Subjects (*n* = 36) in Different Positions on the Mattresses: Mean (*M*), Standard Deviation (*SD*), and Analysis of Variance (ANOVA)

	Standard Mattress		Polyurethane Mattress		Polyether Mattress		Gel Mattress		Foam Mattress		
Position	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	ANOVA
Supine	49.2	9.6	32.0	7.0	34.9	10.3	43.6	6.5	47.4	6.2	$F(4, 175) = 31.90^*$
Lateral	87.6	17.6	69.5	16.3	72.9	17.1	77.5	13.9	73.5	12.6	$F(4, 175) = 7.24^*$
Miles-Pauchet	60.5	16.8	38.9	9.5	45.8	10.4	49.2	10.3	53.0	6.9	$F(4, 175) = 18.38^*$
Fossa	—	—	52.5	12.3	62.4	16.5	77.2	14.5	79.0	15.8	$F(3, 140) = 25.88^*$

$^*p < .001$.

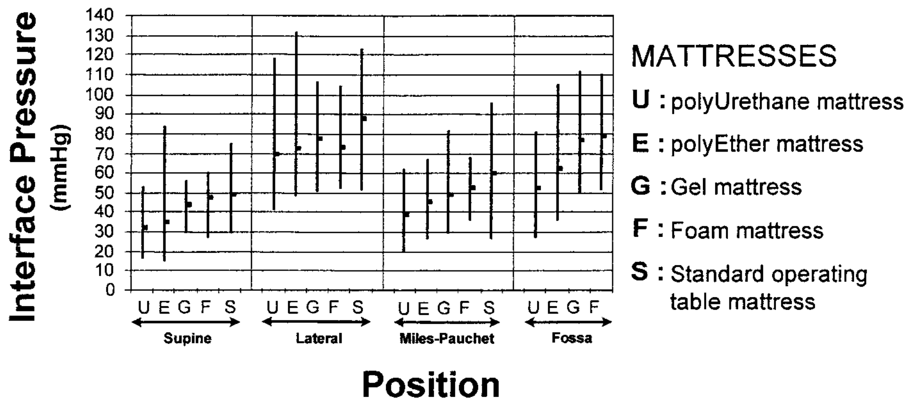

Figure 3. Pressure by position and mattress type: mean, minimum and maximum.

DISCUSSION

The maximum interface pressures on operating-table mattresses were high. The maximum interface pressures in the supine position varied between 32.0 and 69.5 mmHg. The pressure surface on which the patient rests is small because of the thin mattress and the hard surface of the operating table. The body weight has to be distributed over this small area, which implies a higher interface pressure.

Table 3. Comparison of Effect of Subjects' (n = 36) Position on Operating-Table Mattresses: Tukey Test (level of significance)

Position	Standard Mattress	Polyurethane Mattress	Polyether Mattress	Gel Mattress
Supine position				
Polyurethane mattress	<.001	—		
Polyether mattress	<.001	.55	—	
Gel mattress	.03	<.001	<.001	—
Foam mattress	.88	<.001	<.001	.29
Lateral position				
Polyurethane mattress	<.001	—		
Polyether mattress	.001	.88	—	
Gel mattress	.04	.19	.73	—
Foam mattress	.001	.81	1.00	.82
Miles-Pauchet position				
Polyurethane mattress	<.001	—		
Polyether mattress	<.001	.07	—	
Gel mattress	<.001	.001	.70	—
Foam mattress	.04	.61	.05	.61
Fossa position				
Polyether mattress	—	.03	—	
Gel mattress	—	<.001	<.001	—
Foam mattress	—	<.001	<.001	.96

The incidence of pressure ulcers may be reduced, but not entirely eliminated, by using pressure-reducing operating-table mattresses. The period of immobilization is long and the interface pressures remain high. The American Guidelines for Pressure Ulcer Prevention (Panel for the Prediction and Prevention of Pressure Ulcers in Adults, 1992) as well as the Dutch Consensus on Pressure Ulcers (Bakker, 1992) recommended that at-risk patients be repositioned every 2 or 3 hours. On an operating table, the pressure is not only considerably higher, immobilization is frequently for longer periods of time. Consequently, the risk of pressure ulcer development is high during the operating period. Close regular inspection of the skin and early preventive measures are important. Pressure ulcers do not become visible immediately. A patient can easily be transferred from the operating room to a nursing unit without any visible sign of a pressure ulcer, which could have been caused during the operation yet developed several days later (Vermillion, 1990). This is especially frustrating for the nurses of the surgical units—despite all their efforts, the patient develops a pressure ulcer after all—but it may also give the operating room nurses the false impression that the necessary preventive measures were taken and that no extra attention is required.

Interface pressures were highest in lateral position. All pressure-reducing mattresses tested generated a significantly lower interface pressure in this position when compared with the standard operating-table mattress. Pressure reduction varied between 10.1 and 18.1 mmHg. Interface pressure, however, remained high (average 69.5 to 87.6 mmHg). None of the mattresses reduced interface pressure sufficiently in the lateral position. The mattresses became fully compressed under the weight of the body. A ‘‘bottoming out’’ effect was seen and the subject rested on the hard surface of the operating table. It is not likely that a thicker mattress will significantly reduce interface pressure. The supporting surface is small and there is little tissue mass between bone and skin, allowing only limited pressure distribution. For this position especially, it is crucial that the patient’s position be altered postoperatively. It is therefore essential to report what the patient’s position was during surgery to ensure not only a careful inspection of the high-risk pressure surfaces, but also, if possible, to allow a different postoperative positioning of the patient so as not to overload the pressure surfaces concerned.

In the Miles-Pauchet position, the pressure surface is reduced and part of the leg weight is shifted to the sacrum. When placing a patient in this position, there is the danger of increased shearing force at sacrum height. Slightly tilting the pelvis to relieve the traction from the tissue may reduce the shearing force and decrease the risk of pressure ulcers.

The foam mattress seems to have little or no pressure-reducing effect and cannot contribute to the prevention of pressure ulcers.

Although the interface pressure on the gel mattress was significantly lower than on the standard operating-table mattress, the reduction in the interface pressure was limited. Therefore, minimal pressure ulcer prevention is to be expected. Based on the American Guidelines for Pressure Ulcer Prevention (Panel for the Prediction and Prevention of Pressure Ulcers in Adults, 1992) in which a turning interval of 2 to 3 hours was suggested for bedridden patients, an operation of more than 2 hours on a standard mattress may involve an increased risk for pressure ulcers. In such circumstances, the pressure-reducing effect of a gel mattress is insufficient. In the fossa and supine positions, both foam mattresses performed significantly better compared with the gel mattress. In the Miles-Pauchet position, the polyurethane mattress performed significantly better than the gel mattress. This is consistent with the findings of Hoyman and Gruber (1992), that replacing gel mattresses with better pressure-relieving systems decreased the incidence of pressure ulcers in surgical patients from 18.9 to 2.7%.

The visco-elastic polyurethane and polyether mattresses had the best pressure-reducing qualities. The results are consistent with those of Hoshowsky and Schramm (1994) who also found that a visco-elastic mattress was more effective than a foam, gel, or standard foam mattress. The visco-elastic mattresses are clearly preferred in the prevention of pressure ulcers on an operating table. Interface pressures were lowest in every position on the polyurethane mattress, but the difference only became significant in comparison to interface pressures measured on polyether mattress in the fossa position.

Given the high differences in interface pressure according to position, position should be taken into account as a variable in all research on pressure ulcer development.

SUMMARY

The interface pressure on an operating table is high. Considering the long period of immobilization during the surgical procedure, the risk of pressure ulcers cannot be underestimated.

The foam mattress tested had little or no pressure-reducing qualities in comparison with the standard operating-table mattress. The pressure-reducing effect of the gel mattress tested was also limited. The visco-elastic polyether and polyurethane mattresses tested had the best pressure reducing qualities and are preferable in the prevention of pressure ulcers on an operating table.

There was not a significant pressure decrease in every position. Interface pressure in lateral position remained high. Consequently, the risk of pressure ulcer development continues to be present.

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