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Use of Pressure Mapping to Compare Two Operating Room Surfaces in the Supine With Bent Knees Position and the Supine in Lithotomy Position

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ABSTRACT

Introduction. Hospital-acquired pressure ulcer/injury (HAPU/I) often occurs postoperatively despite preventative interventions. The authors recently found an increasing incidence of HAPU/I in patients having prolonged operating room (OR) procedures in both the bent knee and lithotomy positions. **Objective.** The aim of this study was to measure and compare 2 different OR surfaces in both the supine with bent knees position and the supine in lithotomy position. The authors sought to identify the most effective pressure redistribution surface in different positions to prevent HAPU/I in surgical patients. **Materials and Methods.** Using a pressure mapping device, the authors measured and compared 5 volunteers on the standard OR surface and on the standard surface with the static, air-filled cushion on top. **Results.** Use of the static, air-filled seat cushion placed on top of the standard OR surface resulted in lower peak pressures and higher skin contact surface area than the standard OR surface alone. **Conclusions.** This study showed that use of the static, air-filled seat cushion on top of the standard OR surface resulted in superior pressure redistribution properties in both the supine with bent knees position and supine in lithotomy position compared with the standard OR surface alone.

KEY WORDS

hospital-acquired pressure ulcer/injury, pressure mapping, operating room surfaces, pressure ulcer, bent knees position, lithotomy position

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A pressure ulcer/injury (PU/I) can occur during prolonged surgical procedures in the operating room (OR).[1] Such injury commonly occurs in anatomic areas in which soft tissues are subject to sustained mechanical loading (ie, pressure) between the bony anatomy (eg, sacrum, heel, ischium) and an external structure (eg, OR mattress, wheelchair).[2] This loading or pressure occurs during prolonged surgical procedures in which the patient is immobilized for longer than 1 to 2 hours and in patients with low perfusion pressure.[1] This persistent pressure obstructs capillary blood flow to the area under pressure and may affect the deep or superficial tissues.[2] Recent publications suggest that pressure redistribution surfaces applied on top of the OR table mattress may decrease the risk of PU/I.[3-5] Few studies have been conducted to determine which surfaces and what patient positioning may achieve sufficient pressure redistribution to decrease intraoperative PU/I.

A 2015 article by some of the authors of this current study focused on pressure mapping OR surfaces using the science of measured peak pressures and surface area to promote the use of an air-filled seat cushion placed under the sacrum during supine procedures.[5] Use of static, air-filled seat cushions for supine positioning in the OR resulted in a 65% reduction in sacral PU/Is that originate in the OR over a 5-year period. In that earlier study the static, air-filled seat cushion was not tested for patients in the supine with bent knees position or the supine in lithotomy position, and the use of this cushion in either of those patient positions was not previously promoted.

Statement of purpose

The purpose of this study was to measure the pressure redistribution properties of the standard OR mattress as compared with use of the standard OR mattress with the static, air-filled seat cushion placed on top of it (ie, placed under the buttocks), with patients in the supine with bent knees position or the supine in lithotomy position.

Research question and significance to perioperative nursing

The surgical team, including nursing staff, is responsible for assessing, planning, implementing, communicating, and documenting the collaboration of care in the perioperative area (before, during, and after surgery). Patient positioning is an important part of this team effort and is done under the direction or delegation of the attending surgeon.[6,7] The surgical team must have a working knowledge of the "how" and "why" of positioning equipment, the necessary safety measures, and the integration of any equipment with the surgeon's practice preference. Patient positioning is influenced by the clinical location of the surgical site, optimal site access, surgeon experience, collateral injury, and patient safety.[8]

OPERATIONAL DEFINITIONS

- Interface pressure: The pressure load between the skin and the support surface; measured in mm Hg.
- Peak interface pressure: The highest pressure load between the skin and the support surface; measured in mm Hg.
- Average interface pressure: The average pressure load between the skin and support surface of a full body or the specific area calculated by the pressure mapping device; measured in mm Hg.
- Skin contact area: The total contact area between the skin and the support surface; measured in inches squared (in^2).
- Pressure redistribution: The pressure relief to a small, concentrated area and the distribution of the pressure over a larger surface area.

Literature review

A literature review for studies focusing on the OR, lithotomy positioning, and pressure mapping found few publications that focus specfically on preventing PU/I. Many studies focus on prevention of other safety factors (eg, preventing nerve damage) or on intraoperative maintenance of skin integrity in general. The authors found few studies on lithotomy positioning and prevention of pressure injuries to the sacral area.

Universal concern exists regarding maintaining skin integrity intraoperatively.[9,10] Studies have shown an increased likelihood of preserving skin integrity by reducing interface pressure and using pressure redistribution devices appropriate to the specific positioning of the patient.[11] Additionally, the use of silicone dressings has been found to reduce the risk of intraoperatively acquired PU/I by protecting skin from shearing force, friction, and moisture.[9,10] It has been noted, however, that although surgical positions are standardized, each patient is unique. That is, each patient has a specific health history and body composition that makes them more or less prone to skin injury; thus, individualized interventions are necessary to address pressure redistribution, avoid shear and friction, and manage moisture.[12]

In a study published in 2017, Mizuno and Takahashi[13] measured pressure to the sacral area in healthy volunteers (N = 21) in the lithotomy position. They investigated the relationship between external pressure (EP) in the sacral region and the physical characteristics of sex, height, weight, and body mass index (BMI). Pressure was measured using a pressure mapping system, a device used to sense EP. Four different pressure measurements were obtained for each subject: box pressure, peak box pressure, contact pressure, and peak contact pressure. The authors did not find a significant correlation between biological sex and BMI in the 4 types of EP measurement over the sacrum with study participants in the lithotomy position.

Kirkland-Walsh et al[5] conducted pressure mapping of 50 volunteers on 4 different OR surfaces. Each participant acted as their own control: (1) on the standard foam OR mattress; (2) on the standard OR mattress with the static, air-filled seat cushion; (3) on a self-contouring gel/foam mattress; and (4) on a fluid immersion simulation mattress. Although the average interface pressure was similar for all 4 surfaces, the air-filled seat cushion on top of the standard OR mattress demonstrated the best pressure redistribution properties, with the lowest sacral peak pressure (35.8 mm Hg) and the largest surface area (250.2 in^2).

Conceptual framework

Pressure mapping is based on a model derived from a classic study conducted by Kosiak[14] and a conceptual model on the etiology of PU/I.[2] The 1959 study evaluated the interface pressure on skin over time, and it explained how EP in a specific area could lead to vaso-occlusion, resulting in decreased tissue perfusion and possibly ischemia in deep and superficial tissues in the area under pressure.

Kosiak[14] used a cutoff of 32 mm Hg as the upper limit for measuring surface interface pressure. An interface pressure of 32 mm Hg or less is considered to be a useful guideline for determining the efficacy of the redistribution properties of the surface being measured and for reducing the risk of PU/I.[15,16]

MATERIALS AND METHODS

This quality improvement study involved volunteer nurses and multiple pressure measurements for a comparative measures design in which participants were measured in different positions on 2 different surfaces. Volunteers recruited were all quality and safety nurses and OR nurses who had a specific interest in the relationship between pressure on the sacrum during OR procedures that involved the supine with bent knees position or the supine in lithotomy position.

A convenience sample of 5 nurses participated in the study (2 male, 3 female). Study participants were recruited from hospital staff, and BMI varied (mean, 26.6 kg/m^2 [range, 23.0–32.0 kg/m^2]). Eligibility criteria included volunteers who were willing to come in on a Saturday to participate in this project and who agreed to self-report height and weight, spend their day in the OR pressure mapping different surfaces, lie on 2 different surfaces in multiple positions for pressure mapping, and wear standard hospital scrubs during measurement. This study was performed as a quality improvement project by the authors of this article.

The authors tested the supine with bent knees position for simulated total knee replacement, and Yellofin Stirrups (Allen Medical) were used for standardizing the supine in lithotomy position. The pressure areas were tested for comparisons on the standard 3-layer viscoelastic memory foam OR mattress and the same standard OR mattress with a static, air-filled seat cushion on top of it.

Pressure mapping is a noninvasive, objective, and reliable means of measuring the interface pressure between the body and the surfaces measured. The pressure mapping technique may be used widely for both seated and lying positions. Typically, pressure mapping has been used in research and in defining the pressure redistribution properties of a surface.[3]

To evaluate the pressure redistribution properties of the surfaces, the authors used the full-body interface pressure mapping system for testing, which has been found to be valid and reliable in measuring interface pressure.[3,5,7] Pressure mapping systems are composed of a mat that contains pressure sensing materials that send data to a computer program. The data are displayed as a color-coded map and as grids for providing numerical pressure values in each area. The numerical values are expressed in millimeters of mercury (mm Hg) and reflect the pressure between the body and the surface measured.

Instrument used

The instrument used for measuring the interface pressure for this comparative study was the XSENSOR X3 PX100 system (XSENSOR Technology Corporation). This system consists of a thin, 99.06 cm × 220.98 cm full-body pressure mapping pad with 1664 sensing points. The sensors in the pad have 3.175 spatial resolutions. The pad was placed between the volunteer and the support surface and connected to the X3 display for real-time pressure mapping recording.

The static, air-filled seat cushion measured 18 in × 18 in and was placed over the standard OR mattress in the above position of lithotomy (**Figure**). The cushion was placed to lie beneath the patient's lumbar area down to the ischial tuberosities for the supine with bent knees position and the supine in lithotomy position.

All participants were instructed to lie in the designated position for 5 minutes on each surface before measurements were recorded on the pressure mapping device. This 5-minute "settling time" was recommended and performed in the authors' previously published study of pressure mapping OR surfaces.[5] The data were displayed on the screen for a minimum of 1200 frames per participant and were recorded on each surface in both the supine with bent knees position and the supine in lithotomy position. The collected data were then downloaded to a computer using X3 medical v6.0 software. The recorded peak pressures and skin contact surface areas were then transcribed into Excel (Microsoft Corporation) spreadsheets by 2 investigators, and all measurements were validated by 2 investigators and the statistician.

Analysis

Paired *t* tests were used to test for differences in pressure (with and without the static, air-filled seat cushion). The authors adjusted for type I error inflation owing to multiple testing by correcting for the false discovery rate (FDR) as per Hochberg and Benjamini.[17] An FDR *P* value of .05 was considered significant. All statistical analyses were conducted using SAS software for Windows version 9.4 (SAS Institute Inc).

RESULTS

As shown in **Table 1**, with the volunteers in the supine with bent knees position the average mean difference in interface pressure between the standard OR surface and the standard OR surface with the static, air-filled seat cushion placed on top of it was not significant. The difference

Figure. Photograph of the pressure mapping pad placed atop the operating room table.

Table 1. Surface comparison: standard OR mattress with and without static, air-filled seat cushion (supine with bent knees position)

VARIABLE	STANDARD MATTRESS (MEAN±SD)	STANDARD MATTRESS WITH STATIC, AIR-FILLED SEAT CUSHION (MEAN±SD)	*P* VALUE	FDR *P* VALUE
Average interface pressure (mmHg)	26.98±1.07	26.46±1.37	.48	.55
Peak interface pressure (mmHg)	75.6±13.62	55.36±9.01	.023	.042[a]
Skin contact surface area (in^2)	359.69±23.47	393.75±39.22	.012	.035[a]

OR: operating room; SD: standard deviation; FDR: false discovery rate adjusted *P* value
[a] Indicates statistical significance
Standard: Three-layer visco-elastic memory foam

Table 2. Surface comparison: standard OR mattress with and without static, air-filled seat cushion (supine in lithotomy position)

VARIABLE	STANDARD MATTRESS (MEAN±SD)	STANDARD MATTRESS WITH STATIC, AIR-FILLED SEAT CUSHION (MEAN±SD)	*P* VALUE	FDR *P* VALUE
Average interface pressure (mmHg)	28.74±1.87	27.46±1.65	.0016	.014 [a]
Peak interface pressure (mmHg)	92.82±24.44	51.94±7.69	.0085	.035 [a]
Skin contact surface area (in^2)	331.87±43.62	369.06±53.19	.018	.041 [a]

OR: operating room; SD: standard deviation; FDR: false discovery rate adjusted *P* value
[a] Indicates statistical significance

in mean peak interface pressure was statistically significant, however. The mean peak pressure for the supine position with bent knees on the standard OR mattress was 75.6 mm Hg, compared with 55.36 mm Hg for the same position on the standard OR mattress with the static, air-filled seat cushion ($P < .023$; FDR $P < .042$). The mean skin contact surface area was significantly less with the standard OR mattress alone compared with the standard OR mattress plus the static, air-filled seat cushion (359.69 in^2 and 393.75 in^2, respectively; $P < .012$).

As shown in **Table 2**, with volunteers in the supine in lithotomy position the average mean interface pressure was significantly different depending on whether the standard OR mattress alone or the standard OR mattress with the addition of the static, air-filled seat cushion was used (28.74 mm Hg and 27.46 mm Hg, respectively; $P < .0016$). The mean peak interface pressure with use of the standard OR mattress alone was significantly greater than with the additional use of the static, air-filled seat cushion (92.82 mm Hg and 51.94 mm Hg, respectively; $P < .0085$). The mean total skin contact surface area was significantly greater with the standard OR mattress in combination with the static, air-filled seat cushion than with the standard OR mattress alone (369.06 mm Hg and 331.87 mm Hg, respectively; $P < .018$).

DISCUSSION

The optimal surface for pressure redistribution to avoid PU/I would have the lowest peak pressures and the largest or highest measured surface area.[3,5] As Teleten et al[3] noted in 2019, this phenomenon can be explained by comparing the wearing of a stiletto shoe with a different type shoe, such as a nursing shoe. The wearer's weight remains the same regardless of which type shoe is worn, but with the stiletto the peak pressures are concentrated over the ball of the foot where the surface area is smaller.

This study was developed from previous work performed by 3 of the investigators.[5] In that previous study, in which 4 surfaces were compared, the lowest peak pressure with the highest surface area was achieved using the air-filled seat cushion on the standard OR surface with the subjects lying flat.

Of the 2 surfaces the authors tested on the 5 volunteers in this study, the combination of the standard OR mattress with the static, air-filled seat cushion on top of it proved most effective for pressure redistribution in both the supine position with bent knees and the supine in lithotomy position. These results suggest that the interface pressure during the supine in lithotomy positioning is better redistributed with the use of the static, air-filled seat cushion in combination with the standard OR mattress than with use of the standard OR mattress alone.

LIMITATIONS

This study has some limitations. It was conducted with a small number of highly motivated, healthy nurse volunteers in a closed OR setting rather than with hospital patients in the OR. A further limitation was that the study participants self-reported their BMI. Additionally, these volunteers were not under anesthesia, nor could actual perfusion under pressure within capillaries be measured; therefore, hemodynamics was not pharmacologically altered in the same way as it would be in surgical patients. Future work should include the effect of OR positioning on pressure distribution over bony prominences over time and should include real patients under anesthesia as well as a larger sample size. Additional data are needed on correlations between perfusion pressure and pressure redistribution over the sacrum during surgical procedures with patients in the supine with bent knees position or the supine in lithotomy position.

Another limitation is that the authors did not investigate the measured pressure over time of surgery. The duration of surgery is a risk factor for the development of PU/Is.[1,17] Prolonged surgical time and increased pressure over the sacrum during procedures in the supine in lithotomy position or the supine with bent knees position would theoretically increase the incidence of PU/I. Previous research indicates that for every 1 hour in surgery, the odds of developing a PU/I increase by 20%.[1]

As mentioned previously, further study should include a larger number of participants, a longer period of time, and participants under anesthesia. Ideally, these participants would more closely align with the general surgical patient population and include older adults as well as patients with morbid obesity. Both these groups are at increased risk for skin breakdown.

CONCLUSIONS

Using the proprietary system mentioned previously, the authors performed pressure mapping of 5 nurse volunteers on 2 different surface types in both the supine with bent knees position and the supine in lithotomy position. The comparisons of interface pressures showed that the combination of the standard OR mattress with the static, air-filled seat cushion placed under the buttocks provided the lowest peak pressures and the highest skin surface contact area. Scant research has been done on static, air-filled seat cushions and patient positioning for PU/I prevention in the OR setting. More studies are needed to determine how long the cushion remains effective in redistributing pressure with surgical patients of all sizes and for different types of surgery. The noninvasive pressure redistribution measurement system studied herein could become a significant tool for estimating the amount of pressure exerted over time in the perioperative setting that may contribute to the development of a PU/I. Results from this study will be used to promote the use of the static, air-filled seat cushion under the buttocks and hips during surgeries that involve the supine with bent knees position and the supine in lithotomy position.

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