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MECHANICAL EVALUATION OF SUPPORT SURFACE IN PERIOPERATIVE POSITIONING

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Abstract. *Foam-based devices are aimed at redistributing pressure from body structures to prevent pressure injury. They are manufactured to control pressure, shear or frictional forces, maintenance of the microclimate or other therapeutic functions. The objective is to evaluate the interface pressure exerted on bony prominences with the use of viscoelastic polymer support surfaces. The analysis was clinical regarding a quasi-experimental study in which repeated measures of twenty healthy volunteers were evaluated in a standard operating table with viscoelastic polymer overlap and compared with the non-use of this support surface. The participants were placed in dorsal decubitus at a surgical table to evaluate the interface pressure in the bony prominences of the occipital, subscapular, sacral, and calcaneal regions. Two evaluations were performed for each bone prominence with the use of sensors. Descriptive analyses and variance test were performed. The mean interface pressure was higher in the viscoelastic polymer than in the non-use of these support surfaces in the occipital ($p < 0.001$), subscapular ($p = 0.022$), sacral ($p < 0.001$), right calcaneus ($p = 0.057$) and left calcaneal ($p = 0.041$). The viscoelastic polymer did not reduce the interface pressure when compared to the non-use of these support surfaces.*

Keywords: *Patient Positioning; Patient Safety; Perioperative Care; Perioperative Nursing; Perioperative Period; Pressure Ulcer*

1. INTRODUCTION

According to the Special Secretariat for the Rights of Persons with Disabilities, assistive technology is an area of knowledge, with an interdisciplinary encompasses products, resources, methodologies, strategies, practices and services that aim to promote the functionality, related to the activity and participation, of people with disabilities or reduced mobility, aiming at their autonomy, independence, quality of life and social inclusion (Brasil, 2009). Support surfaces are technologies developed for this purpose.

Coating materials, upholstery, and integrated systems used for redistribution of body pressure are termed support surfaces. These structures are designed to control the pressure, shear, and friction of tissues, maintaining the microclimate and therapeutic functions (McNichol et al., 2015). The objective of redistribution of body pressure is to prevent complications such as pressure lesions (LPP) (NPUAP, 2017) and compartment syndrome (Sergio et al., 2012).

LPP is localized damage to the skin and underlying soft tissue usually over bone prominence or may still be related to medical equipment or another type of device. The lesion may present as intact skin or as an open ulcer and can be painful. Occurs as a result of intense and prolonged pressure or pressure combined with shear. Tolerance of soft tissue to pressure and shear can also be affected by microclimate, nutrition, perfusion, associated diseases, and soft tissue condition (NPUAP, 2017).

The etiology of LPP involves the interface pressure, characterized by soft tissue compression at the interface between bony prominences and surgical surfaces. Exposure to interface pressure for prolonged periods decreases tissue perfusion and oxygenation of different layers of the skin (Defloor and Schuijmer, 2000; King and Bridges, 2006; Kirkland-Walsh et al., 2015; McInnes et al., 2015).

The literature does not indicate an acceptable threshold for interface pressure. However, there is evidence that the mean capillary refill pressure is 32 mmHg, and this criterion was adopted for evaluating interface pressure because the external pressure that exceeds this level may obstruct blood flow (Defloor and Schuijmer, 2000; King and Bridges, 2006; Kirkland-Walsh et al., 2015; McInnes et al., 2015).

Many products are being designed to redistribute pressure in the surgical patient during prolonged procedures. However, there is little research that evaluates the efficacy of pressure redistribution properties of these products (Kirkland-Walsh et al., 2015).

The viscoelastic polymer was selected because it is a highly recommended static support surface for clinical surgical practice (McInnes et al., 2015) and is often used as a test surface (Defloor and Schuijmer, 2000).

There are gaps in knowledge about viscoelastic polymer behavior in the redistribution of interface pressure due to delays in technological advances in health (Kirkland-Walsh et al., 2015), methodological limitations, and lack of standardization in the classification of support surfaces (McNichol et al. 2015). Few studies have so far determined redistribution of the interface pressure of these materials in the surgical environment.

The objective of this study is to evaluate the interface pressure exerted on bony prominences with the use of viscoelastic polymer support surfaces.

2. METHODS

2.1 Study Design

A quasi-experimental and interdisciplinary study was conducted out at two research centers located in two partner universities in the Triângulo Mineiro region of Minas Gerais, Brazil, specialized in two academic areas: nursing and mechanical engineering.

2.2 Sample

The participants were non-randomly selected from the academic community of the two partner universities by invitation via e-mail. The message contained information about the study's objectives, the importance of participation in the study, and the risks and benefits of participation. The inclusion criteria were being older than 18 years old and could present chronic comorbidities as long as these were controlled. The exclusion criteria were the presentation of cutaneous lesions, impairment of bony prominences, or absence of limbs.

The literature does not present the parameters for the calculation of sample size for evaluation of interface pressure. Therefore, an initial sample of 20 participants was selected, and the statistical power was analyzed later. A significance level of 0.05 was used to estimate the statistical power. Statistical power was estimated for differences in mean interface pressure between evaluations. The statistical power of 99% was achieved within the limits of statistical program accuracy. In clinical and practical terms, there was a difference in interface pressure peaks, which justified not including more participants in the study.

2.3 Data Collection Procedure

The research was conducted in a large public teaching hospital in the state of Uberaba, Minas Gerais, Brazil. Data were collected in April 2017 on the weekends (Saturday and Sunday) in the morning, afternoon, and night, and during workdays, at night because none of the scheduled surgeries were performed in these periods. The data were collected by a Ph.D. student after receiving training in anthropometric measurement and interface pressure evaluation.

The study participants were sent to the hospital's anthropometry room, and the objective of the study was clarified, and each participant signed an informed consent form. The participants were asked to undress and put on a hospital gown open on the back and designed explicitly for the study. The weight and height of the participants were measured, and body mass index (BMI) was calculated by dividing the weight in kilograms by the square of the height (World Health Organization - WHO, 2000).

Weight was measured using a Filizola analog scale with a precision of 0.1 kg. The participants were weighed barefoot, standing, with their arms hanging alongside the body. Height was measured using a vertical stadiometer scaled in centimeters and millimeters. The participants were positioned on the scale barefoot, heels together, and feet are forming a 45° angle, in an upright position, with eyes fixed on the horizon. Readings were done to the nearest centimeter when the horizontal rod of the vertical bar on the scale touched the participant's head (WHO, 2000).

The nutritional status was determined according to guidelines of the WHO as follows: underweight, BMI < 18.5 Kg/m^2; healthy weight, BMI of 18.5–24.9 Kg/m^2; overweight, BMI of 24.9–29.9 Kg/m^2; and obese, BMI > 29.9 Kg/m^2. Five participants from each nutritional status were selected.

The participants were assessed for standard procedures adopted in the hospital. In typical situations, this involves positioning the patient on a standard operating table (SOT). The patient was placed on the SOT in the supine position, covered with a cotton sheet, with the upper limbs supported by supine clamps. The SOT was a Barrfab surgical table (212 cm × 59 cm) containing a foam mattress covered with a waterproof lining. Interface pressure on the SOT is considered the control measurement, evaluated in each bony prominence region (occipital, subscapular, sacral, and calcaneal). The surgical suite had a Barrfab SOT, and air conditioning to control room temperature and relative humidity to ensure that the conditions for our patients were the same as those for patients subjected to anesthetic-surgical procedures.

After evaluation of interface pressure in SOT, viscoelastic polymer (Akton) evaluation was performed. The dimensions of the viscoelastic polymer were 183.0 cm x 50.0 cm x 1.3 cm, and the manufacturer reported that this product did not require a cover made of other materials.

The interface pressure was measured using a mesh of sensors, the CONFORMat system (Tekscan®) (Figure 1). This system uses Windows-based software and includes a thin and flexible sensor consisting of 1,024 sensing elements to measure interface pressure in a tissue area of 530 mm x 617 mm. At the time of assessment, the calibrations were changed for each evaluation.

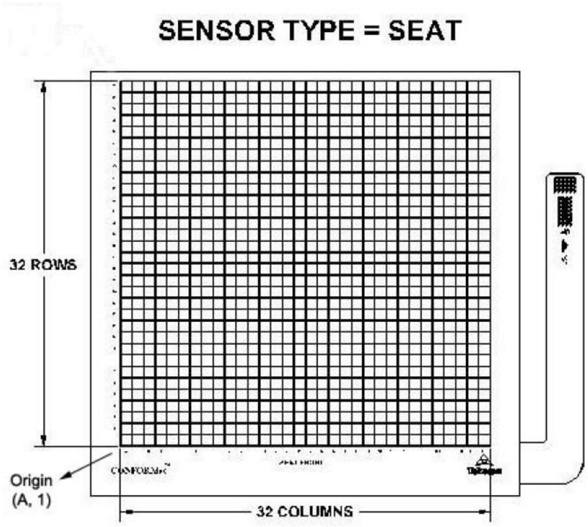

Figure 1. Sensor mesh. Source: System Manual CONFORMat.

The sensing elements are arranged in rows and columns in the sensor mesh. The software uses a map to convert the pressure detected by the hardware into pressure data and correctly display the sensor output in the window in real time (Figure 2 and 3). The sensor had been previously calibrated for use with each support surfaces. At the time of assessment, the calibrations were changed for each SS.

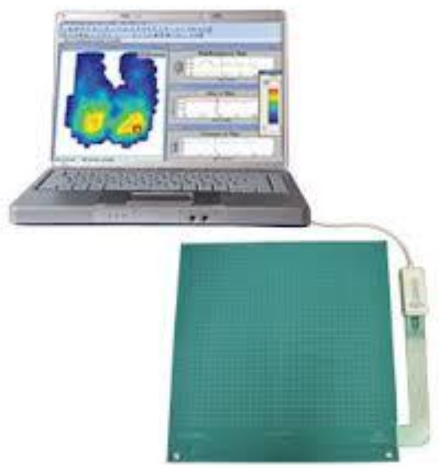

Figure 2. Mesh of sensors connected by the handle to the USB cable. Source: CONFORMat® System Manual.

Figure 3. Software CONFORmat® connected to the sensor network. Uberaba (MG), 2017.

Interface pressure was evaluated in each bony prominence region (occipital, subscapular, sacral, and calcaneal). It should be pointed out that the experiment involved evaluations of all the support surfaces in this study. These regions were selected because of their higher rate of PU in the supine position. For measuring each body prominence, the volunteers remained in the supine position for one minute, which was the time required to complete the film of the image's detection frames

The participants were asked to indicate when they were relaxed before starting film recording and not to move or speak during measurements. The mean peak pressure values were determined in millimeters of mercury (mmHg). Before placing the participant on the CONFORMat sensor, the adequacy of the positioning and distribution of the sensors was checked to ensure they were under the regions to be evaluated. Measurements were made along the caudal-cephalic axis because of the size of the sensor and were initiated in the occipital and subscapular regions. The participant was repositioned when necessary, and the sensor was placed in the sacral region and then in the calcaneal region.

2.4 Data Processing and Analysis

These data were entered into Excel spreadsheets and, after double data entry and validation, were analyzed using the Statistical Package for Social Sciences software version 20.0 for Windows.

The qualitative variables (types of the support surface and nutritional status) were analyzed by descriptive statistics using absolute frequencies, percentage distributions, and contingency tables. For the quantitative variables (age, BMI, and mean peak pressure), descriptive measures of centrality (mean) and dispersion [standard deviation (SD), and minimum and maximum values were used.

Analysis of variance (ANOVA) of repeated measures for a single factor was used to assess statistically significant differences between the support surfaces for the pressure exerted on the occipital, subscapular, sacral, and calcaneal bony prominences.

For numerical variables, repeated-measures ANOVA for multiple factors was used to verify statistically significant differences according to nutritional status (underweight, normal weight, overweight, and obese). The level of significance was 5%.

2.5 Ethical Considerations

This study was approved by the Research Ethics Committee of the Federal University of Triângulo Mineiro (Protocol No. 48855615.6.0000.5154) by the precepts of National Health Council Resolution 466/2012 of the Ministry of Health of Brazil.

3. RESULTS AND DISCUSSION

The mean age of the study participants was 28.2 years, ranging from 19.0 to 59.0 years. Most of the study sample were women (90%).

The minimum BMI was 16.73 Kg/m^2, with a maximum of 44.96 Kg/m^2 and a mean of 25.85 Kg/m^2.

The mean peak interface pressure was higher on all bony prominences on the viscoelastic polymer compared to the SOT (Tables 1).

The use of the viscoelastic polymer did not mean a reduction of the interface pressure when compared to the standard operating table. The sensor evaluation images of a participant are illustrated below (Figure 4).

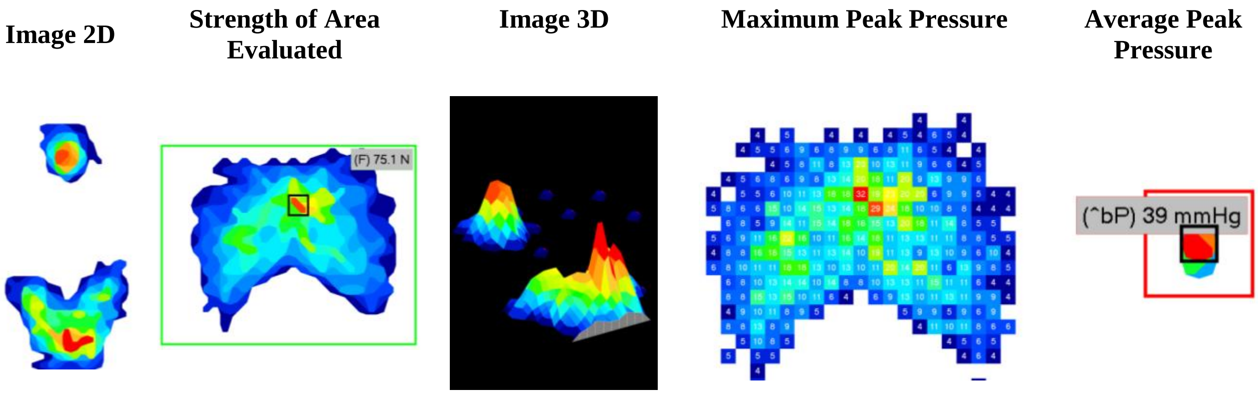

Figure 4: Image capture models by the CONFORmat® sensor. Uberaba (MG), 2017.

The mean interface pressure was relatively higher in the sacral and left calcaneal regions using the viscoelastic polymer, corresponding to 42.90 and 36.55 mmHg, respectively.

Mean values of maximum interface pressure were significantly higher in the occipital and sacral regions (p = 0.001) with the use of the viscoelastic polymer.

A multivariate, multiple-factor analysis was performed to assess differences in the mean peak interface pressure between the study groups according to nutritional status (underweight, healthy weight, overweight, and obese). There were no significant differences between the groups (p=0.87) (Table 2).

Table 1: Distribution of the mean values, standard deviations, and minimum and maximum mean peak interface pressure in the occipital, subscapular, sacral, right calcaneal, and left calcaneal regions for the standard operating table and viscoelastic polymer. Uberaba (MG), Brazil, 2017.

Region			Occipital	Subscapular	Sacral	Right Calcaneus	Left Calcaneus
Mean Peak Interface Pressure (mmHg)	Mean	SOT*	23.40	21.65	25.65	23.80	27.85
		Viscoelastic Polymer	32.80	32.30	42.90	31.35	36.55
	SD†	SOT*	5.43	12.14	9.83	8.63	9.09
		Viscoelastic Polymer	7.80	12.82	17.45	12.77	14.52
	Minimum	SOT*	15.00	12.00	14.00	7.00	11.00
		Viscoelastic Polymer	22.00	12.00	24.00	16.00	19.00
	Maximum	SOT*	33.00	68.00	48.00	45.00	47.00
		Viscoelastic Polymer	48.00	63.00	94.00	60.00	77.00
p‡			<0.001	0.022	0.001	0.057	0.041

*SOT- standard operating table; † SD- standard deviation; ‡ p- p-value.

Table 2: Distribution of the mean values, standard deviations, minimum and maximum values of mean peak pressure in the sacral region compared by nutritional groups for the different support surfaces. Uberaba (MG), Brazil, 2017.

Variables	Nutritional Classification		Standard Operating Table	Viscoelastic Polymer
Mean peak interface pressure (mmHg) F*=0.29 p†=0.87	Underweight	Mean	29.80	42.80
		Standard Deviation	14.81	29.07
	Eutrophic	Mean	25.40	41.60
		Standard Deviation	11.63	13.05
	Overweight	Mean	24.00	45.00
		Standard Deviation	7.65	18.71
	Obese	Mean	23.40	42.20
		Standard Deviation	3.85	8.53

*F: analysis of the variance value of the repeated measures for multiple factors; †p: p-value.

The precise measurement of interface pressure depends on several factors, including equipment calibration and the proper use and number of sensing elements per tissue area. A higher number of sensing elements per tissue area may increase measurement sensitivity. The number of sensors per tissue area in the equipment used in the present study was higher than that in other studies that used pressure mapping technologies (Defloor and Schuijmer, 2000; King and Bridges, 2006; Bergstrand et al., 2015; Miller et al., 2013).

A previous study found a positive relationship between body composition and interface pressure and proposed a virtual reference model for the action of tension on the analyzed tissue. In this study, the stress caused by interface pressure was more evident in the muscle layer. Furthermore, there was no relationship between the fat layer and a higher level of muscle shearing (Oomens et al., 2003).

An experimental laboratory study in Belgium mapped interface pressure on different support surface using ErgoCheck System detection technology, which is composed of 684 sensors (Defloor and Schuijmer, 2000). The Mapping System, with four sensors in a mesh of 45 cm by 45 cm, was adopted for a cross-sectional study in a university hospital in Sweden (Bergstrand et al., 2015); and the XSensor System, with a square resolution of 0.25 inches for an extension of 48 inches by 48 inches, was employed by North Americans researchers in experimental laboratory research (King and Bridges, 2006) meaning that the technologies utilized for areas of detection by sensors were inferior to that used in the present study.

An experimental study that evaluated the pressure distribution properties of an electrophysiology lab surface and an operating room table pad used the FSA Mapping System, which is a mesh of 1,024 sensors in a detection area of 1920 mm x 762 mm (Miller et al., 2013). Even though the number of sensors corresponds to that used in the present study, the detection area of the FSA Mapping System is 4.5 times larger, which could interfere with the evaluation's sensitivity.

In a study that evaluated mean interface pressure in the supine position carried out in the United States, the technology used to evaluate pressure was an electro-pneumatic sensor (Blaylock and Gardner, 1994). There is no information in the study about the dimensions of the sensor or other specifications, which makes it difficult to make comparisons about the technology used.

As for the immobilization time of the participants to carry out interface pressure measurement, the methodology proposed in the present study follows that of other studies, which have reported that immobilization time did not alter pressure detected by sensors (Defloor and Schuijmer, 2000; Defloor and Grypdonck, 2000).

Viscoelastic polymer presented the highest values compared to the control in the evaluation of interface pressure. In studies with different research designs, the outcomes resulted in recommendations not to use viscoelastic polymer, or it was considered that evidence as to its use was not yet sufficient to make a recommendation (Huang et al., 2013; McInnes et al., 2015).

It should be pointed out that differences in nomenclature for some support surface can leave doubts about the materials investigated in the research. For example, in the experimental laboratory study in Belgium (Defloor and Schuijmer, 2000), the viscoelastic polymer was called gel support surface.

An integrative review carried out by the Wound, Ostomy, and Continence Nurses Society, also observed inconsistencies about terminology for support surface (McNichol et al., 2015). The standardize the nomenclature is needs since differences in terminology hamper comparison between studies.

A study conducted in Belgium compared four support surfaces about interface pressure of the SOT, which included: gel support surface (Action®); support surface made of 3-cm foam; viscoelastic polyether support surface (SAF®); and a viscoelastic polyurethane support surface (Tempur-Pedic®). The gel material (Action®) showed a significant reduction of interface pressure about the SOT (43.6 mmHg and 49.2 mmHg, respectively) (Defloor and Schuijmer, 2000). These data do not agree with those of the present study, in which Action® viscoelastic polymer presented higher levels of interface pressure about the SOT.

An experimental laboratory study that evaluated pressure distribution properties compared a 2.5-inch surface (Tempur-Pedic® EP) constructed of viscoelastic material (Tempur-Pedic North America, Inc, Lexington, KY) with a 4-inch viscoelastic surface (Medline Industries, Inc, Mundelein, IL). The 4-inch viscoelastic surface had sensors that recorded the highest interface pressure as being 90 mmHg (Miller et al., 2013). In the present study, the highest interface pressure found was when testing the viscoelastic polymer in the sacral region (94 mmHg).

The results of the present study showed the highest interface pressure in the sacral and calcaneal regions, mainly in the control measurements and in readings for the viscoelastic polymer, which corroborates the conclusions of a retrospective chart review to determine what factors contribute to the development of PU in patients who undergo surgical procedures (Engels et al., 2016).

An experimental laboratory study found that the sacral region had higher mean values of peak pressure for Eggcrate® support surface compared to the SOT (59 ± 17 mmHg, p=0.01) and the use of gel (61 ± 27 mmHg, p=0.02). For the heels, using Eggcrate showed a lower mean value for peak pressure (70 ± 24 mmHg) compared to the SOT (122 ± 58 mmHg, p=0.02) and the use of gel (134 ± 59 mmHg, p=0.005) (King and Bridges, 2006). The values presented with the SOT were higher than the value found in the present study.

About the calcaneal region, the results of a study in the United States indicated that pressure on the heel was high for most surfaces (King and Bridges, 2006), which is in agreement with the findings of the present study. These data imply the need to implement actions to relieve this pressure whenever possible when this region is elevated.

The results showed no statistically significant differences between groups when analyzing interface pressure and considering nutritional classification. It is essential to consider that nutritional classification, even though it is a crucial evaluation criterion that is used by many researchers, expresses only a relationship between two variables (body weight and height). People with the same nutritional classification may have different body compositions (ratio of lean body mass, fat mass, and amount of water), which may be why no correlation between BMI and interface pressure was found.

A relationship between body composition and interface pressure was observed in a study that proposed a virtual model of reference about the action of tension on the tissue. In this study, the stress caused by interface pressure was more evident in the muscle layer. Furthermore, there was no relationship between the fat layer with a higher level of muscle shearing (Oomens et al., 2003).

Considering differences in research findings, it is essential, not only to evaluate interface pressure but also to take into consideration the fact that ulcer etiology has multiple causes. Among these characteristics is the tolerance of tissue to pressure and shearing, which may be affected by microclimates (heat and humidity), as well as aspects related to nutrition, perfusion, associated diseases and tissue conditions (NPUAP, 2017). Body composition is also relevant since different types of tissue have different reactions to pressure.

One of the limitations of the present study is the participation of healthy volunteers. Although the data collection was done in environmental conditions similar to those to which surgical patients are exposed, some factors related to the procedure should be considered. Anesthesia and the patient's clinical condition interfere in the body's hemodynamics and are risk factors for PU. Furthermore, surgical procedures involve adding operative fields and surgical manipulation, which could increase pressure in certain areas. Another aspect that can be considered as a limitation of the study is that the majority of the participants were women since interface pressure distribution can be influenced by the deposition of adipose tissue in different regions. However, it should be pointed out that, even though these issues were not considered, the purpose of the study was achieved.

4. CONCLUSION

The use of the viscoelastic polymer as a support surface did not reduce and not standardize the interface pressure levels when compared to the standard operating table.

The study shows that is a need for higher investments in new technologies for the development of support surfaces that offer safety in surgical positioning. Also, it directs attention to the need to carry out new clinical studies on the use of these materials.

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7. RESPONSIBILITY NOTICE

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