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Skin Protection With Hydrofibre Foam and Silicone-Based Dressing Can Help Prevent Pressure Injuries: A Preliminary Evaluation in Brazil

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ABSTRACT

Understanding skin microclimate—the temperature and humidity at the interface between the skin and other surfaces—is critical for preventing pressure injury (PI). This prospective case series evaluated the performance of a hydrofibre multilayer foam dressing with silicone coating in managing the sacral microclimate in intensive care patients with intact skin at high PI risk when used with a standard PI prevention protocol. Sacral temperature and humidity were measured using a thermographic imaging camera and electrical bioimpedance device, respectively. These data were collected daily for a maximum of 7 consecutive days. Data of 25 patients were analysed. The mean sacral humidity during the first 4 days of dressing use was 20.7%. Its levels reduced on Days 5 and 6 and later returned to Day 2 levels on Day 7. The sacral temperature showed no sudden change with dressing use. Correlations between sacral microclimate and smoking, alcohol, systemic arterial hypertension, and diabetes mellitus were determined. There was no evidence of PI among the participants during the 7-day follow-up. The hydrofibre multilayered foam dressing with silicone coating effectively managed the sacral microclimate in high-risk intensive care patients, highlighting its potential utility in PI prevention protocols.

1 | Introduction

Pressure injuries (PIs) are localised damage to the skin and underlying soft tissue caused by prolonged intense pressure, including compression and shearing, and other aetiologies [1]. PIs usually occur over bony prominences or are related to medical devices. They may present as intact skin or an open ulcer [1]. Pressure ulcers develop from direct pressure and compression exerted on small vessels in the skin, which restricts oxygen supply at the capillary interface and leads to oedema and ischaemia in the skin, muscle, and fascia, resulting in tissue death and ulcers [1, 2]. The extent of tissue damage depends on the duration and intensity of the applied pressure and/or shear forces [1, 2].

Another independent and critical external predictor of PI development is the skin microclimate, which refers to the environmental conditions, specifically humidity and temperature, at the contact surface between the skin and clothing or other surfaces [3]. Therefore, understanding the dynamics of skin microclimate is essential to prevent PI. Research suggests that a relative increase in skin temperature can predict reactive hyperaemia in the sacral

Summary

- The development of pressure injuries (PI) is a key indicator of patient safety during hospitalisation and is considered preventable with appropriate measures.
- This study assessed the effectiveness of hydrofibre multilayer dressings (coated with soft silicone adhesive) in managing skin microclimate when incorporated into a standard PI prevention protocol.
- Prophylactic hydrofibre multilayer foam silicone dressings are moisture-wicking materials that draw moisture away from the skin, ensuring optimal levels of humidity and temperature, thereby reducing the risk factors associated with PI development.
- Incorporating hydrofibre multilayer foam silicone dressings into standard preventive care protocols in intensive care settings may lower the incidence of PIs.

region. A 1°C increase in skin temperature increases the risk of tissue ischemia in the sacral region by 14-fold [4] and is correlated with the development of stage I or II PI in critically ill patients [5, 6]. Further, pre-clinical and clinical evidence suggests that a 1°C or 2°C increase in skin temperature for 24–96 h can trigger PI [7, 8]. Humidity is another indicator of PI development according to the Braden Scale and can be quantified via sensors or bioimpedance [9, 10]. Increased skin moisture contributes to its maceration and rupture [11], weakening the stratum corneum and making the skin more vulnerable to external forces [12].

Strategies to prevent PI emphasise reducing both magnitude and duration of pressure and shear forces [13]. This includes the use of appropriate supporting surfaces, such as mattresses, cushions, and dressings, with regular patient repositioning [13]. There is also a growing interest toward using multilayer dressings with silicone as supportive prophylaxis to prevent PIs. Such coverage helps redistribute pressure and shear forces over a larger area, reducing localised pressure on the skin [14]. Additionally, these dressings contain a polyurethane foam layer that absorbs excess local moisture, helping to maintain skin microclimate balance [15–17]. Multilayer dressings are promising prophylactic interventions, as preventive measures are up to 2.5 times more economical for treating skin lesions [18]. Hydrofibre multilayer dressings with soft silicone adhesive have a multi-layered absorbent pad containing a layer of polyurethane foam and a layer of hydrofibre (sodium carboxymethylcellulose fibre) that can absorb wound fluid and bacteria. The hydrofibre component (gelling fibre) of the dressing absorbs excess moisture and helps maintain a moist environment in the wound, which is crucial to balance the microclimate, making it a potential preventive agent [19–23]. Further, the gelling action helps minimise dead space, where bacteria generally grow, and maintain moisture balance in the wound bed, creating an optimal environment for wound healing [20, 24–29]. These dressings can lock in exudate and trap bacteria, protect peri-wound skin, and reduce maceration. Additionally, the silicone adhesive can minimise wound- and cross-infection during removal [30–34].

Information on the effectiveness and cost-effectiveness of prophylactic dressings is limited and focuses on a specific dressing. Additionally, there is a gap in evidence on the clinical efficacy of these dressings in controlling modifiable external factors and preventing PI. This study aimed to evaluate the impact of a hydrofibre multilayer dressing with soft silicone adhesive on skin microclimate when incorporated into a standard PI prevention protocol in intensive care unit (ICU) and semi-ICU patients with intact skin at high risk of PI.

2 | Materials and Methods

2.1 | Study Design and Patients

This prospective study with a 7-day follow-up was conducted in the ICUs and semi-ICUs of a medium-sized private hospital (can cater to 50 patients in critical care) in São Paulo, SP, Brazil, between October 2020 and March 2021. Owing to the ongoing coronavirus pandemic at the time of the study, only 20 beds were available for data collection. The study assessed the effects of a hydrofibre multilayer dressing with soft silicone adhesive (Aquacel Foam Pro, ConvaTec Inc.) designed to protect the skin from breakage caused by friction, shearing, and humidity, when used as part of a PI prevention protocol [19]. The study protocol conformed to the tenets of the 1975 Declaration of Helsinki and was approved by the institutional ethics committee, which is accredited by the National Commission for Ethics in Research of the Brazilian Ministry of Health (CAAE 36736720.3.0000.5485). All participants or their legal representatives provided written informed consent.

The study included hospitalised patients (hereafter referred to as the study group [SG]) aged 18–90 years with intact skin, expected to stay in the ICUs/semi-ICUs for at least 7 days, with moderate, high, and very high risk of developing PI (according to the classification obtained by the Braden Scale). The patients were required to present with intact sacral skin suitable for the application of the study dressing. Patients treated in ICUs and semi-ICUs were selected because they are at risk of developing PI and are routinely assessed with the Braden Scale. The institutional minimum preventive measures protocol recommended a change in position every 2 h, use of a pyramidal mattress, daily inspection of the skin in areas with bony prominences, and use of a multilayer covering with silicone adhesive changed every 4 days. However, if the covering were intact, the dressing could remain for up to 7 days. ICU patients at end of life, diagnosed or suspected of having coronavirus, who could not be repositioned for clinical reasons, with known/documented allergies to substances used in the study dressing, or diagnosed with stage II PI or higher were excluded.

2.2 | Study Procedures

Three different researchers collected data: a researcher (enterostomal therapist nurse at the hospital institution—PE1), a research monitor (nurse outside the hospital, research monitor—MP), and another researcher (enterostomal therapist nurse not linked to the institution—PE2). Their duties included admitting patients to the study, collecting socio-demographic data, and filling out the Braden Scale and the clinical and microclimate assessment instruments. A research coordinator, blinded throughout data collection, compiled the data and helped analyse and interpret them. All participants were accommodated in Hill-Rom Versa Care beds (Hill-Rom, Batesville, IN) with

33-density traditional foam mattresses and received standard PI prevention strategies, including routine assessment of the risk of developing lesions using the Braden Scale, periodic repositioning, and skin care (Table 1). The dressing was removed daily to inspect the skin and assess the microclimate and temperature parameters, after which it was quickly reapplied. The cover was changed as necessary based on dirt, faeces, and/or urine infiltration or when the edges were curled and peeling off.

Skin temperature and humidity are generally used to describe the microclimate for PI [35]. An SKN1501 Skin Detector (Skin Condition Check, Houston, TX) was used to measure skin moisture in the sacral region. Through electrical bioimpedance, the equipment measures, with 98% accuracy, the moisture and oiliness inside the skin's stratum corneum. The measurements are expressed in percentages, with the values for normal and dry skin ranging from 40% to 60% and 15% to 25%, respectively. Local skin temperature was measured using a model T540 thermographic camera with a 24° lens (FLIR Systems, Wilsonville, OR, USA), with an IR resolution of 464×348 and NETD of 40 mK at 30°C, with a measurement range of −20°C to 120°C and an accuracy of ±2% or 2°C. Both skin temperature and humidity were assessed before applying the dressing, corresponding to the baseline levels.

The thermography camera was calibrated based on each patient's Brain Tunnel Temperature prior to use by taking an image of the patient's face, focusing on the central region and inter-eye distance, and the region where the core temperature is read (hypothalamus). The image of the sacral region was taken from a distance of 30 cm, with the patient in the lateral decubitus position and the region framed to identify the area and contour of the body. The microclimate assessment focused on the sacral region, with the periumbilical skin area serving as the control site. These regions were inspected daily for signs of PI and/or skin alteration. Patients were followed up for 7 consecutive days of hospitalisation in the ICU or semi-ICU.

2.3 | Statistical Analysis

Data were analysed descriptively and inferentially. Continuous variables were described using mean and standard deviation (SD) and compared using the Mann–Whitney test. Categorical variables were presented as absolute and relative frequencies and compared using the chi-square test. The relationships between microclimate measurements and other categorical variables were investigated using the Mann–Whitney test and compared using the chi-square test. The significance level was set at 5% ($p < 0.05$).

3 | Results

3.1 | Demographic and Baseline Characteristics

Twenty-five patients were included in the SG (Table 2). the most common comorbidities were systemic arterial hypertension (SAH; 64%) followed by diabetes mellitus (DM; 40%). the most common oxygenation method was spontaneous breathing (57.7%), followed by mechanical ventilation (19.2%) and use of nasal catheter (15.4%). the mean (SD) total Glasgow scale score was 13.8 (1.1). Braden scale assessments indicated a high risk for PI (mean [SD] score 10.1 [1.0]). use of adult diapers for micturition was the most common method of urinary elimination (56%), and no cases of faecal incontinence were observed. common primary diagnoses in the sg included neurological (27.5%), cardiovascular (23.5%), and pulmonary diseases (23.5%), followed by infections (21.6%).

3.2 | Skin Microclimate Humidity

Skin microclimate humidity was measured before and after applying the hydrofibre multilayer silicone foam dressing at the sacral skin (Table 3) and periumbilical skin (control group; Table 4). The mean microclimate humidity of the sacral skin was 20.8% (SD 6.3) at baseline (Day 1) and 22.1% (SD 9.1) on Day 7 (corresponding to the sixth day of using the multilayer silicone foam dressing) (Table 3). Notably, although the mean microclimate humidity remained 20.7% in the first 4 days of applying the hydrofibre multilayer silicone foam dressing, it substantially reduced at the fifth and sixth collections before returning to the levels of the second collection on Day 7 (Table 3). In contrast, the average (SD) microclimate moisture in the periumbilical region increased from 21.4% (8.1) at the fifth collection to 26.2% (8.2) at the sixth collection with a significant difference between the fourth and fifth ($p = 0.013$) and the fifth and sixth ($p = 0.046$) collections (Table 4).

Correlations between the humidity at the sacral region and smoking, alcohol consumption, SAH, and DM were assessed.

TABLE 1 | Procedures performed in the study group.

Procedures	Timing
Sociodemographic assessment	ICU/semi-ICU admission
PI risk assessment—Braden scale	From admission to the ICU/semi-ICU and daily, for up to 7 consecutive days
Clinical evaluation	In the first 24 h of ICU/semi-ICU admission and daily, for up to 7 consecutive days
Skin inspection and microclimate measurements	From admission to the ICU/semi-ICU and daily for up to 7 consecutive days
Application of the hydrofibre multilayer foam dressing	ICU/semi-ICU admission; or exchange when necessary

Abbreviations: ICU, intensive care unit; PI, pressure injury.

TABLE 2 | Clinical and sociodemographic characteristics.

Characteristics	Study group ($n = 25$)
Age, mean ± SD	69.3 ± 16.2
Female/male, *n* (%)	19 (76)/6 (24)
Colour/race, *n* (%)	
White	23 (92.0)
Black	1 (3.8)
East Asian	1 (3.8)
Smoker, *n* (%)	
Never	22 (88.0)
Current or past	3 (12.0)
Alcoholism, *n* (%)	
Never	21 (80.8)
Current or past	4 (15.4)
Systemic arterial hypertension, *n* (%)	16 (64.0)
Diabetes mellitus, *n* (%)	10 (40.0)
Vasoactive drug, *n* (%)	8 (32.0)
Oxygenation, *n* (%)	
BIPAP	2 (7.7)
Nasal catheter	4 (15.4)
Spontaneous	15 (57.7)
Face mask	0 (0.0)
Mechanical ventilation	5 (19.2)
Glasgow scale, mean ± SD	13.81 ± 1.12
Braden score, mean ± SD	10.08 ± 1.03

Abbreviations: BIPAP, bilevel positive airway pressure; SD, standard deviation.

there was a significant difference in the mean and maximum humidity values between individuals with and without DM, with an average humidity of 22.6% ± 5.8% ($p = 0.013$) and maximum humidity of 31.9% ± 8.2% ($p = 0.023$) in participants with DM. although some comorbidities have been correlated with fluctuations in humidity and temperature (microclimate determinants), such a correlation was not observed in the SG.

3.3 | Skin Microclimate Temperature

The microclimate temperature measurements in the sg revealed a mean (SD) temperature of 36.3°C (0.7) at the first collection and 36.0°C (1.1) at the seventh collection (Table 5). comparison of the mean skin microclimate temperature across different collections in each patient showed no statistically significant difference ($p = 0.900$ and 0.648 for the first and last collections, respectively). this was also true for measurements across different days. the mean microclimate temperature at the sacral region was maintained at 35.2°C (Table 5). the thermographic scan of both sacral and umbilical regions showed a more homogeneous distribution of temperature in the SG without a sudden change in tonality (Figure 1). the scan identified points of higher and lower temperature along the sacral region.

There was a statistically significant difference ($p < 0.001$) in the mean temperature of individuals who had never smoked (35.4°C ± 0.8°C) and those who had smoked or still smoke (33.4°C ± 1.8°C). similarly, the maximum temperature of individuals who had never smoked (36.3°C ± 0.8°C) differed from that of individuals who had smoked or still smoke (34.8°C ± 1.4°C) ($p = 0.001$). the maximum temperature was also different ($p = 0.008$) between individuals with a history of alcohol consumption (34.9°C ± 1.5°C) and those without (36.2°C ± 0.8°C). a similar difference ($p = 0.042$) was observed between patients diagnosed with SAH (35.9°C ± 1.0°C) and those who were not (36.6°C ± 0.6°C).

4 | Discussion

This study is one of the first to assess the effect of a hydrofibre multilayer silicon foam dressing on the skin microclimate of patients at risk of PI admitted to the ICU and semi-ICU in Brazil. The findings underscore the clinical relevance of hydrofibre technology in effectively managing skin and wound

TABLE 3 | Microclimate humidity measurements in the sacral and periumbilical region.

	Moisture (%) sacral region				Moisture (%) periumbilical region		
	n	Mean[a]	Median	SD[a]	*n*	Mean[a]	SD
1st collection	25	20.76	19.6	6.294	25	23.18	7.186
2nd collection	25	21.40	20.6	7.372	25	22.01	8.445
3rd collection	25	19.58	18.4	7.406	25	22.38	6.886
4th collection	23	21.02	19.9	8.486	23	24.75	8.031
5th collection	22	18.33	18.1	6.614	22	21.42	8.128
6th collection	18	16.02	13.1	6.146	18	25.39	7.694
7th collection	15	22.06	19.8	9.066	15	23.05	6.826

Abbreviation: SD, standard deviation.
[a]Mean and SD, Mann–Whitney test.

TABLE 4 | Moisture measurements in the periumbilical region (study group).

Moisture (%) periumbilical region		Paired differences					
		Average	SD	95% confidence interval of the difference	t^a	df	*p*
Pair 1	1st–2nd collection	1.16800	9.02943	−2.55917, 4.89517	0.647	24	0.524
Pair 2	2nd–3rd collection	−0.36800	8.75408	−3.98151, 3.24551	−0.210	24	0.835
Pair 3	3rd–4th collection	−2.72174	6.83700	−5.67828, 0.23480	−1.909	22	0.069
Pair 4	4th–5th collection	3.39545	5.85983	0.79735, 5.99356	2.718	21	0.013
Pair 5	5th–6th collection	−4.16667	8.20767	−8.24825, −0.08509	−2.154	17	0.046
Pair 6	6th–7th collection	3.17333	8.85982	−1.73307, 8.07974	1.387	14	0.187

Abbreviation: SD, standard deviation.
[a]Student's *t*-test for paired samples.

TABLE 5 | Temperature measurements in the sacral region (study group).

Temperature (°C) sacral region	Study group			
	n	Mean[a]	Median	SD[a]
1st collection	25	35.29	35.6	1.668
2nd collection	25	35.23	35.3	1.075
3rd collection	25	35.16	35.4	1.424
4th collection	23	35.22	35.6	1.463
5th collection	22	35.30	35.4	0.853
6th collection	18	35.50	35.5	0.791
7th collection	15	35.31	35.7	1.746

Abbreviation: SD, standard deviation.
[a]Mean and SD, Mann–Whitney test.

microclimate, including temperature and moisture, and potentially aiding to prevent PI. The ability of hydrofibre dressings to manage excess moisture and maintain temperature stability presents an innovative approach to support PI prevention [20, 21, 31, 32].

In the context of PI, microclimate refers to the temperature and humidity between the patient's skin and support surface. Localised increase in skin temperature or moisture is a known risk factor for PI. Such a microclimate change affects skin cells' morphology and mechanical properties, thereby increasing the susceptibility of the underlying tissue to pressure, frictional forces, and shear distortions [35]. Health conditions involving fever, extensive skin loss, incontinence, severe injuries to the central nervous system, sympathetic nervous system overload, obesity, and excessive sweating can increase body moisture [36]. In the present study, more than half of the participants had diuresis, in addition to obesity and neurological diseases, characterising a subpopulation more vulnerable to changes in the microclimate of the sacral region. The hydrofibre multilayer silicone foam dressing is indicated for protecting vulnerable skin and reducing the potential risk of skin breakdown [37]. It comprises a waterproof and breathable polyurethane barrier that protects the wound from external contaminants, reducing the risk of viral or bacterial infection, and helping to manage moisture vapour transmission of the exudate absorbed by the dressing; soft, flexible polyurethane foam that absorbs excess wound fluid and bacteria; a hydrofibre layer, comprising 100% sodium carboxymethyl cellulose fibres, which creates a soft, cohesive gel conforming to the wound surface, maintains a moist environment in the wound to support healing, and aids autolytic debridement without damaging tissue; and a perforated silicone adhesive layer for secure adhesion to the skin, to allow easy repositioning of the dressing after skin evaluation, and for easy removal [19]. International guidelines support standard prevention measures for PI and interventions for the eventual microclimate imbalance, including application of a multilayer foam covering on bony prominences [38, 39].

In the current study, the hydrofibre multilayer silicone foam dressing effectively controlled the skin microclimate humidity in the sacral region, preventing potential harm to the skin surface. The microclimate humidity in the sacral region decreased from a median 18.1% at the fifth collection to 13.1% in the sixth collection, corresponding to the fifth day of dressing use. Notably, a change in the overall patient's skin humidity, as evidenced by the increase in humidity (21.4% in the fifth collection to 26.2% in the sixth) in the periumbilical region (control region), was not mirrored in the sacral region, which received the intervention under investigation (hydrofibre multilayer silicone foam dressing). The variation in the sacral microclimate humidity may be attributed to the dressing's ability to manage excess moisture. These findings indicate that despite the potential for an increase in the sacral microclimate humidity due to an increase in systemic or regional body humidity, the hydrofibre

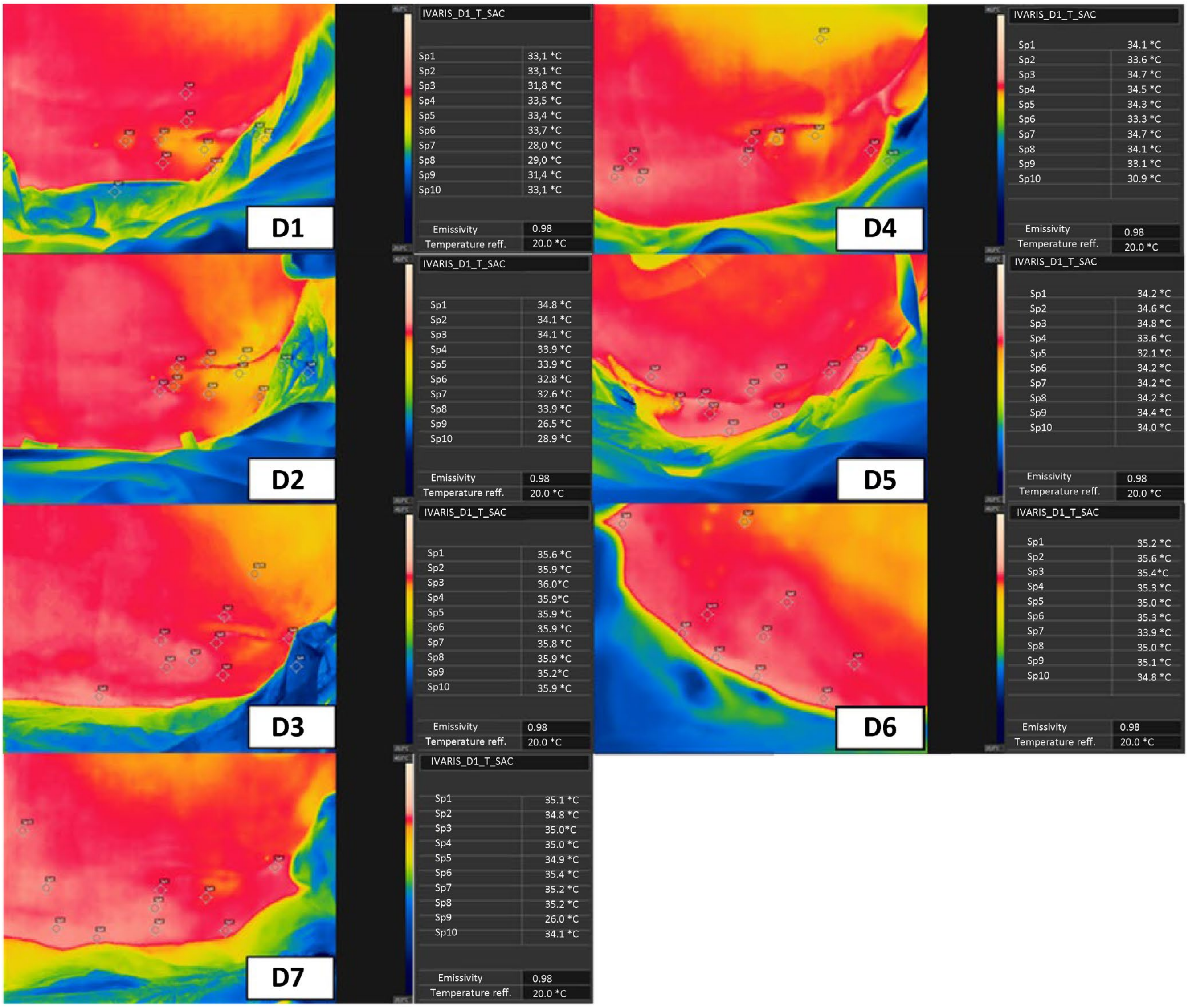

FIGURE 1 | Seven-day thermographic sequencing of the study group. The areas coloured in white (intense) and red are warmer (close to 40°C). the lower temperatures (around 20°C) are indicated in green and blue.

multilayer silicone foam dressing maintained adequate skin hydration by effectively absorbing excess humidity and promoting skin dryness at the application site. The observed increase in the microclimate humidity in the sacral region at the final collection (sixth day of dressing use) likely reflects the saturation point of the dressing, indicating the need for a dressing replacement to preserve its protective function.

The ability to absorb and retain perspiration and excessive moisture from skin with a high moisture vapour transmission rate (MVTR; facilitates the release of moisture to the external surface of the dressing) and impermeability to liquids, such as urine, are desired properties of wound dressings intended to prevent PI [40]. The MVTR of vapour permeable coverings with bidirectional extension implies a greater or lesser accumulation of heat and moisture at the patient/support surface interface, especially for patients with impaired mobility [41]. In this sense, the control of microclimate humidity by the hydrofibre multilayer silicone foam dressing in the sacral region may also be explained by its known high MVTR (13.41 g/10 cm^2/24 h) [42], which may have facilitated the evaporation of the excess absorbed moisture. In addition, the hydrofibre layer, at its interface, is designed to retain and block excess fluid in contact with the skin at at-risk sites [43]. Based on this, modulating the microclimate could be incorporated into care protocols to prevent PI.

The change in microclimate temperature is related to an increased risk of developing PI because high temperatures increase the metabolic demand, enhancing tissue susceptibility to the ischemic effects of pressure and shearing. A 1°C increase in body temperature corresponds to an approximately 10% increase in metabolic consumption [44]. With tissue perfusion already compromised, any increase in metabolic activity could cause ischemia and tissue damage more rapidly than if the body temperature were normal [45]. Thus, it is reasonable to infer that warm skin is more susceptible to ischemic damage and that, under pressure and shear loads, ischemia and cell death may occur earlier, leading to PI [46]. According to the findings of the thermographic sequencing scan, the gradual, but not homogeneous, increase in temperature indicates tissue vulnerability. However, hypothermia nuclei appear on the skin's surface after the deep tissue injury. We hypothesize that this is a summation phenomenon of reduced blood flow, local hypoxia, and shear forces due to dermal arteriole deformation and obstruction [1]. In a prospective observational study with patients undergoing elective surgery, the researchers concluded that an increase in skin temperature was an independent risk factor for PI [47]. Bhargava et al. [48] showed that a localised increase in skin temperature between 0.25°C and 0.9°C may be associated with inflammation. Although patients' PI risk profiles vary widely and depend on the fragility of the individual's tissue, lower heat build-up between the weight-bearing body and the dressing/support favours PI prevention. This indicates the importance of temperature control related to the skin's microclimate at at-risk sites. In the present study, the hydrofibre multilayer foam dressing with silicone-coating proved effective at controlling temperature in the sacral region, with no statistical difference between measurements during the 7-day follow-up.

Most available literature on the use of prophylactic dressings for PI is based on silicone-coated multilayer dressings preventing friction and controlling the shear force between the dressing and skin [49, 50]. The main strength of the current study is that it demonstrated that the benefit of the hydrofibre multilayer foam silicone dressing for preventing PI is based on skin microclimate management in addition to skin friction and shear control [51]. A limitation of the current study is the small sample size, which is attributable to the hospital allocation of a specific number of ICU beds for critically ill coronavirus patients alone. Owing to the human and material resource constraints during the pandemic, the present investigation did not receive approval to be designed as a randomised clinical trial. Consequently, comparison with standard care or an alternative multilayer dressing coated with silicone was unfeasible and warrants further research.

In conclusion, the studied hydrofibre multilayer silicone foam dressing effectively offered skin protection in the sacral region of the study participants by managing skin microclimate moisture imbalance and temperature control, thus aiding in the prevention of PI when used alongside standard care protocols. These results are particularly relevant to PI prevention protocols in ICUs and semi-ICUs.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

1. N. Mondragon and P. M. Zito, *Pressure Injury* (StatPearls, 2024).

2. V. D. Sree, M. K. Rausch, and A. B. Tepole, "Linking Microvascular Collapse to Tissue Hypoxia in a Multiscale Model of Pressure Ulcer Initiation," *Biomechanics and Modeling in Mechanobiology* 18, no. 6 (2019): 1947–1964.

3. A. Gefen, "How Do Microclimate Factors Affect the Risk for Superficial Pressure Ulcers: A Mathematical Modeling Study," *Journal of Tissue Viability* 20, no. 3 (2011): 81–88.

4. C. Lachenbruch, Y. Tzen, D. Brienza, P. E. K, and P. A. L, "The Relative Contributions of Interface Pressure, Shear Stress, and Temperature on Tissue Ischemia: A Cross-Sectional Pilot Study," *Ostomy/Wound Management* 59, no. 3 (2013): 25–34.

5. Suriadi, H. Sanada, J. Sugama, et al., "Risk Factors in the Development of Pressure Ulcers in an Intensive Care Unit in Pontianak, Indonesia," *International Wound Journal* 4, no. 3 (2007): 208–215, https://doi.org/10.1111/j.1742-481X.2007.00315.x.

6. S. Yusuf, M. Okuwa, Y. Shigeta, et al., "Microclimate and Development of Pressure Ulcers and Superficial Skin Changes," *International Wound Journal* 12, no. 1 (2015): 40–46.

7. J. Y. Kokate, K. J. Leland, A. M. Held, et al., "Temperature-Modulated Pressure Ulcers: A Porcine Model," *Archives of Physical Medicine and Rehabilitation* 76, no. 7 (1995): 666–673.

8. W. Sae-Sia, D. D. Wipke-Tevis, and D. A. Williams, "Elevated Sacral Skin Temperature (Ts): A Risk Factor for Pressure Ulcer Development in Hospitalized Neurologically Impaired Thai Patients," *Applied Nursing Research* 18, no. 1 (2005): 29–35.

9. M. Guihan, B. M. Bates-Jenson, S. Chun, R. Parachuri, A. S. Chin, and H. McCreath, "Assessing the Feasibility of Subepidermal Moisture to Predict Erythema and Stage 1 Pressure Ulcers in Persons With Spinal Cord Injury: A Pilot Study," *Journal of Spinal Cord Medicine* 35, no. 1 (2012): 46–52.

10. B. M. Bates-Jensen, H. E. McCreath, and A. Patlan, "Subepidermal Moisture Detection of Pressure Induced Tissue Damage on the Trunk: The Pressure Ulcer Detection Study Outcomes," *Wound Repair and Regeneration* 25, no. 3 (2017): 502–511.

11. C. M. Blattner, G. Coman, N. R. Blickenstaff, and H. I. Maibach, "Percutaneous Absorption of Water in Skin: A Review," *Reviews on Environmental Health* 29, no. 3 (2014): 175–180.

12. M. Geerligs, C. Oomens, P. Ackermans, F. Baaijens, and G. Peters, "Linear Shear Response of the Upper Skin Layers," *Biorheology* 48, no. 3–4 (2011): 229–245.

13. N. Tayyib and F. Coyer, "Effectiveness of Pressure Ulcer Prevention Strategies for Adult Patients in Intensive Care Units: A Systematic Review," *Worldviews on Evidence-Based Nursing* 13, no. 6 (2016): 432–444.

14. N. S. Walsh, A. W. Blanck, L. Smith, M. Cross, L. Andersson, and C. Polito, "Use of a Sacral Silicone Border Foam Dressing as One Component of a Pressure Ulcer Prevention Program in an Intensive Care Unit Setting," *Journal of Wound, Ostomy, and Continence Nursing* 39, no. 2 (2012): 146–149.

15. M. Clark, J. Black, P. Alves, et al., "Systematic Review of the Use of Prophylactic Dressings in the Prevention of Pressure Ulcers," *International Wound Journal* 11, no. 5 (2014): 460–471.

16. N. Santamaria, M. Gerdtz, S. Sage, et al., "A Randomised Controlled Trial of the Effectiveness of Soft Silicone Multi-Layered Foam Dressings in the Prevention of Sacral and Heel Pressure Ulcers in Trauma and Critically Ill Patients: The Border Trial," *International Wound Journal* 12, no. 3 (2015): 302–308.

17. P. Davies, "Role of Multi-Layer Foam Dressings With Safetac in the Prevention of Pressure Ulcers: A Review of the Clinical and Scientific Data," *Journal of Wound Care* 25, no. sup 1 (2016): S3–S23.

18. B. Oot-Giromini, F. C. Bidwell, N. B. Heller, et al., “Pressure Ulcer Prevention Versus Treatment, Comparative Product Cost Study,” *Decubitus* 2, no. 3 (1989): 52–54.

19. ConvaTec Inc., *AQUACEL™ Foam Instructions for Use*, AQUACEL™ foam adhesive and non-adhesive Hydrofiber™ foam dressing. WI-0010, Version 7.0 (ConvaTec Inc, 2023).

20. M. J. Waring and D. Parsons, “Physico-Chemical Characterisation of Carboxymethylated Spun Cellulose Fibers,” *Biomaterials* 22, no. 9 (2001): 903–912, https://doi.org/10.1016/S0142-9612(00)00254-4.

21. J. Hurlow, “AQUACEL Ag Dressing With Hydrofiber Technology,” *Advances in Wound Care (New Rochelle)* 1, no. 2 (2012): 104–107.

22. S. Philbin, “Pressure Ulcer Management Using Sodium Carboxymethylcellulose Hydrofiber Foam Dressings,” *Ostomy/Wound Management* 59, no. 3 (2013): 10–12.

23. A. Krejner and T. Grzela, “Modulation of Matrix Metalloproteinases MMP-2 and MMP-9 Activity by Hydrofiber-Foam Hybrid Dressing - Relevant Support in the Treatment of Chronic Wounds,” *Central European Journal of Immunology* 40, no. 3 (2015): 391–394.

24. M. Walker, J. A. Hobot, G. R. Newman, and P. G. Bowler, “Scanning Electron Microscopic Examination of Bacterial Immobilisation in a Carboxymethylcellulose (Aquacel) and Alginate Dressings,” *Biomaterials* 24, no. 5 (2003): 883–890.

25. S. A. Jones, P. G. Bowler, M. Walker, and D. Parsons, “Controlling Wound Bioburden With a Novel Silver-Containing Hydrofiber Dressing,” *Wound Repair and Regeneration* 12, no. 3 (2004): 288–294, https://doi.org/10.1111/j.1067-1927.2004.012304.x.

26. P. G. Bowler, S. A. Jones, M. Walker, and D. Parsons, “Microbicidal Properties of a Silver-Containing Hydrofiber Dressing Against a Variety of Burn Wound Pathogens,” *Journal of Burn Care & Rehabilitation* 25 (2004): 192–196.

27. M. Walker, P. G. Bowler, and C. A. Cochrane, “In Vitro Studies to Show Sequestration of Matrix Metalloproteinases by Sliver-Containing Wound Care Products,” *Ostomy/Wound Management* 53, no. 9 (2007): 18–25.

28. S. Jones, P. G. Bowler, and M. Walker, “Antimicrobial Activity of Silver-Containing Dressings is Influenced by Dressing Conformability With a Wound Surface,” *Wounds* 17, no. 9 (2005): 263–270.

29. S. M. Bishop, M. Walker, A. A. Rogers, and W. Y. J. Chen, “Moisture Balance: Optimising the Wound-Dressing Interface,” *Journal of Wound Care* 12 (2003): 125–128.

30. G. R. Newman, M. Walker, J. Hobot, and P. Bowler, “Visualisation of Bacterial Sequestration and Bactericidal Activity Within Hydrating Hydrofiber Wound Dressings,” *Biomaterials* 27 (2006): 1129–1139.

31. P. Coutts and R. G. Sibbald, “The Effect of a Silver Containing Hydrofiber Dressing on Superficial Wound Bed and Bacterial Balance of Chronic Wounds,” *International Wound Journal* 2, no. 4 (2005): 348–356.

32. B. J. Robinson, “The Use of a Hydrofiber Dressing in Wound Management,” *Journal of Wound Care* 9, no. 1 (2000): 32–34.

33. M. Walker, J. A. Hobot, G. R. Newman, and P. G. Bowler, “Scanning Electron Microscopic Examination of Bacterial Immobilisation in a Carboxymethylcellulose (Aquacel) and Alginate Dressings,” *Biomaterials* 24, no. 5 (2003): 883–890.

34. P. G. Bowler, S. A. Jones, B. J. Davies, and E. Coyle, “Infection Control Properties of Some Wound Dressings,” *Journal of Wound Care* 8, no. 10 (1999): 499–502.

35. A. Gefen, “How Do Microclimate Factors Affect the Risk for Superficial Pressure Ulcers: A Mathematical Modeling Study,” *Journal of Tissue Viability* 20, no. 3 (2011): 81–88.

36. M. Clark and J. Black, “Skin IQ Microclimate Made Easy,” *Wounds International* 2, no. 2 (2011): 1–6.

37. P. Avsar, Z. Moore, and D. Patton, “Dressings for Preventing Pressure Ulcers: How Do They Work?,” *Journal of Wound Care* 30, no. 1 (2021): 33–39.

38. M. M. Baharestani, J. Black, K. Carville, et al., “Dilemmas in Measuring and Using Pressure Ulcer Prevalence and Incidence: An International Consensus,” *International Wound Journal* 6, no. 2 (2009): 97–104.

39. European Pressure Ulcer Advisory Panel, National Pressure Injury Advisory Panel and Pan Pacific Pressure Injury Alliance. E. Haesler, ed., *Prevention and Treatment of Pressure Ulcers/Injuries: Clinical Practice Guideline. The International Guideline*. (EPUAP/NPIAP/PPPIA, 2019).

40. J. Brown, “The Role of Dressings in the Prevention of Pressure Ulcers,” *British Journal of Nursing* 25, no. S15 (2016): S6–S12, https://doi.org/10.12968/bjon.2016.25.15.S6.

41. M. van Leen, R. Halfens, and J. Schols, “Preventive Effect of a Microclimate-Regulating System on Pressure Ulcer Development,” *Advances in Skin & Wound Care* 31, no. 1 (2018): 1–5.

42. K. Ousey, “A Multipurpose Dressing: A Clinical Review of the Absorption, Debridement and Healing Properties of Aquacel Foam,” *Journal of Wound Care* 28, no. Sup9a (2019): S1–S23.

43. C. D. Weller, V. Team, and G. Sussman, “First-Line Interactive Wound Dressing Update: A Comprehensive Review of the Evidence,” *Frontiers in Pharmacology* 11, no. 155 (2020), https://doi.org/10.3389/fphar.2020.00155.

44. T. W. Hsu, S. Y. Yang, J. T. Liu, C. T. Pan, and Y. S. Yang, “The Effect of Cushion Properties on Skin Temperature and Humidity at the Body-Support Interface,” *Assistive Technology* 30, no. 1 (2018): 1–8.

45. D. Brienza and M. Geyer, “Using Support Surfaces to Manage Tissue Integrity,” *Advances in Skin & Wound Care* 18, no. 3 (2005): 151–157.

46. J. Kottner, J. Black, E. Call, A. Gefen, and N. Santamaria, “Microclimate: A Critical Review in the Context of Pressure Ulcer Prevention,” *Clinical Biomechanics* 59 (2018): 62–70.

47. M. Yoshimura, G. Nakagami, S. Iizaka, et al., “Microclimate Is an Independent Risk Factor for the Development of Intraoperatively Acquired Pressure Ulcers in the Park-Bench Position: A Prospective Observational Study,” *Wound Repair and Regeneration* 23, no. 6 (2015): 939–947.

48. A. Bhargava, A. Chanmugam, and C. Herman, “Heat Transfer Model for Deep Tissue Injury: A Step Towards an Early Thermographic Diagnostic Capability,” *Diagnostic Pathology* 9, no. 1 (2014): 36–42.

49. M. Kohta, S. Yunoki, and J. Sugama, “Effect of Prophylactic Dressings to Reduce Pressure Injuries: A Polymer-Based Skin Model,” *Journal of Wound Care* 33, no. S2 (2024): S4–S9.

50. M. Kohta, T. Urai, S. S. Saad, and J. Sugama, “Multilayered Silicone Foam Dressings Potentially Used for Preventing Recurrence of Pressure Injuries: A Bench-To-Clinical Bedside Study,” *Japan Journal of Nursing Science* 20, no. 1 (2023): e12504.

51. “In-Vitro Performance Characteristics of AQUACEL Foam Pro WHRI4536 MS129,” 2015.