BLADDER INCONTINENCE MOISTURE DETECTION FOR PRESSURE INJURY PREVENTION WITH A NOVEL SMART SURFACE SYSTEM FOR MONITORING AT-RISK PATIENTS IN A POST-ACUTE CARE FACILITY

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Individuals with bowel and bladder incontinence and related incontinence-associated dermatitis (IAD) are five times more likely (95% CI 2.62-9.50) to develop pressure injuries (PI) than those who are continent (Beeckman et al., 2014). Signs of skin damage can be observed within 15 minutes of exposure to moisture (Phipps et al., 2019). Monitoring skin surface moisture and temperature or microclimate in real-time can be challenging (Scheel-Sailer et al., 2015).

Skin Moisture

Excess moisture may stem from incontinence, perspiration, mucus, wound exudate and other bodily fluids. Overhydration of the skin causes the stratum corneum to swell and stretch, weakening the connections between epidermal cells and collagen fibres. Increased permeability and disruption of the normal barrier function renders the skin more susceptible to irritants and mechanical damages. Further, IAD is an independent risk factor for PI (Gray & Giuliano, 2018; Lachenbruch et al., 2016).

Skin Temperature

Elevated skin temperature has also been shown to be a strong predictor for PI development. Although the exact mechanism remains unclear, elevated skin temperature may increase tissue metabolic demand and oxygen consumption, making the skin more vulnerable to mechanical damage (Yarmolenko et al., 2011). In the clinical setting, skin microclimate can be modulated through repositioning to relieve pressure, clothing and linen changes, or interventions such as dressings and the application of medical devices (Kottner et al., 2018). The skin's ability to withstand increased temperature and humidity levels can vary depending on age, comorbidities, and a host of other factors. High and low skin temperature and humidity beyond normal ranges can negatively affect the barrier function (Kottner et al., 2018) and tolerance leading to superficial skin changes (Gefen, 2011).

Aim

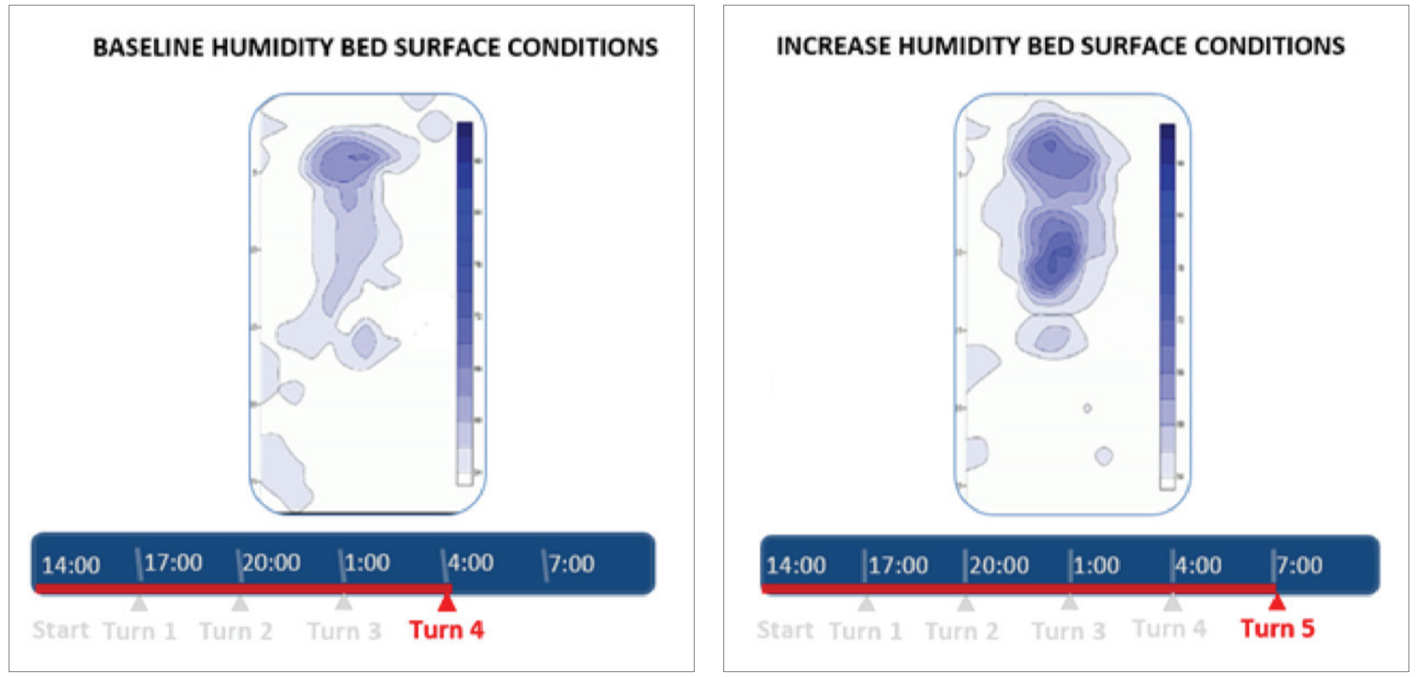
This study aimed to compare the assessment of skin moisture using a smart surface system to clinical evaluation.

Methods

This was a prospective, single-site study conducted at an Ontario tertiary care facility. InterRAI was used to identify at-risk patients who were placed on the smart surface in addition to standardized preventative care. These patients also received regular assessment by nurses for bladder and bowel incontinence 3-hourly over 18 hours. Bladder incontinence status was recorded in the head-to-toe assessment forms. Skin moisture assessments by nurses was compared with those recorded by the smart surface to explore the degree of agreement. For this study,
we focused the analysis on only skin moisture related to bladder incontinence events. At 3-hourly intervals (timed to coincide with manual turns where applicable) a repeat head-to-toe skin assessment was conducted. Any changes in observations from the previous assessment (T1-5) were noted. A bladder incontinence event was assessed visually by expecting the patient's briefs at those time intervals.

The smart surface platform comprises an array of sensors embedded in a thin, flexible surface placed underneath the bedding and not in direct contact with the patient. For the study, two smart surfaces were

***Figure 1** shows a timeline of each turn event with respect to nursing assessments around bladder incontinence status. A screenshot of the smart surface platform sensor data from the bed surface humidity conditions (left), when the patient had no exposure to bladder incontinence, and an increase in humidity (right) after exposure to bladder incontinence are visualized. Screens shots of the gradient of average surface relative humidity levels from the bed surface are visualized from least (light blue) to greatest (dark blue) via percentage. Smart surface platform data screenshots were taken at exact time points of the nursing assessments.*



retrofitted to hospital mattresses. The sensors gathered data from the subject's bedding surface in the form of interface pressure (mmHg), temperature (Celsius) and humidity (0-100% RH) at 4-second intervals. Sensor data was collected and archived on a centralized server at the study hospital. Sensor-generated humidity and temperature data corresponding to each bladder incontinence-related moisture comment were input independently into a smart surface platform model. The model had been previously trained on a small set of bladder incontinence sensor data to classify whether the data at a particular timestamp represents
a *moisture* event or *non-moisture* event.

Results

A total of 104-patients met the inclusion criteria; mean age was 59 years (range 21-92 years, ± 19.15). A total of 132 nurse-recorded bladder incontinence observations were identified in the nurse observation data, and 125 bladder incontinence events were identified by the smart surface platform. The comparison resulted in matching 125 out of 132 bladder incontinence events. This resulted in a 94.7% agreement. Using a binomial test, this result was found to be statistically significant (*P*<.05).

Table 1: Overview of trial results related to patient bladder incontinence events. All tests of equal or given proportions of smart surface data accuracy produced P-values of less than .05.

Number of times nurses recorded bladder incontinence events	Number of times smart surface platform data bladder incontinence correlated
n = 132	n = 125, 94.7% ([95]% CI = ([89]%, [98]%))

Implications

Study results demonstrate a high degree of agreement between nursing assessments and evaluation by the smart surface system of excess skin moisture due to bladder incontinence. This demonstrates the potential value for using the sensor to continuously monitor patients' skin moisture to mitigate risk for moisture associated skin damage. Continuous microclimate monitoring by the sensor can trigger an incontinence event accurately, shown in table 1. The sensors can be used to assist nursing with incontinence management by accurately detecting just-in-time increase in skin moisture thereby reducing unnecessary nurses' time-spent checking a patient's incontinence status at the bedside and reducing the risk of developing PIs. Decreasing exposure time (the duration from the bladder incontinence moisture event to when a brief or wicking product is replaced) is an important aspect of IAD and PI prevention.

The technology's ability to accurately measure PI risk factors supports nursing practice. Supplementary data generated has the potential to improve resource allocation by informing targeted microclimate management strategies and decreasing unnecessary interventions. The large volume of data collected will be used as a basis for artificial intelligence (AI) applications with the potential to inform other clinical decision-making areas.

References

1. Beeckman D, Van Lancker A, Van Hecke A, Verhaeghe S. A systematic review and meta-analysis of incontinence-associated dermatitis, incontinence, and moisture as risk factors for pressure ulcer development: review of moist skin and pressure ulcers. Res Nurs Health. 2014;37(3):204–18. https://doi.org/10.1002/nur.21593
2. Gefen A. How do microclimate factors affect the risk for superficial pressure ulcers: a mathematical modeling study. J Tissue Viability 2011;20:81–8. https://doi.org/10.1016/j.jtv.2010.10.002
3. Gray M, Giuliano KK. Incontinence-associated dermatitis, characteristics and relationship to pressure injury: a multisite epidemiologic analysis. J Wound Ostomy Continence Nurs. 2018;45(1):63-67. https://doi.org/10.1097/WON.0000000000000390
4. Kottner J, Black J, Call E, Gefen A, Santamaria N. Microclimate: A critical review in the context of pressure ulcer prevention. Clin Biomech. 2018;59:62-70. https://doi.org/10.1016/j.clinbiomech.2018.09.010
5. Lachenbruch C, Ribble D, Emmons K, Vangilder C. Pressure ulcer risk in the incontinent patient: analysis of incontinence and hospital-acquired pressure ulcers from the international pressure ulcer prevalence™ survey. J Wound Ostomy Continence Nurs. 2016;43(3):235-41. https://doi.org/10.1097/WON.0000000000000225
6. Phipps LA, Gray M, Call E. Time of onset to changes in skin condition during exposure to synthetic urine. J Wound Ostomy Continence Nurs. 2019;46(4):315–320. https://doi.org/10.1097/WON.0000000000000549
7. Scheel-Sailer A, Frotzler A, Mueller G, Annaheim S, Rossi RM, Derler S. Challenges to measure hydration, redness, elasticity and perfusion in the unloaded sacral region of healthy persons after supine position. J Tissue Viability. 2015;24(2):62–70. https://doi.org/10.1016/j.jtv.2015.03.002
8. Yarmolenko PS, Moon EJ, Landon C, Manzoor A, Hochman DW, Viglianti BL, et al. Thresholds for thermal damage to normal tissues: An update. Int J Hyperthermia. 2011 Jun;27(4):320–43. https://doi.org/10.3109/02656736.2010.534527

Keywords: pressure injury, incontinence-associated dermatitis, wound microclimate, sensor technology, artificial intelligence, machine learning.

This study was supported by a grant from Centre for Aging, Brain Health Innovation (CABHI), with cofunding from Curiato Inc. (Waterloo, Ontario).

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