Correlating nocturnal heel pressure to morning heel perfusion using sensors

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BACKGROUND

- Pressure ulcers (PU) develop when ongoing pressure is applied to skin, causing capillary compression, decreased oxygenation, and skin breakdown
- PUs are associated with reduced mobility, pre-existing vascular and skin conditions[1]
- PUs are a significant cause of morbidity and mortality
- Prevalence of PU in Canadian acute care settings is estimated at 25%[2] and are costly to treat:
  - $44,000- $90,000 per hospital-acquired PU
  - $11,000 to $18,500 per community-acquired PU[3]
- Our research team has more than two decades of experience researching smart sensors that support aging and quality of life
- New pressure mat technology provides the ability to monitor pressure continuously, and Infra-red (IR) cameras can help identify micro-circulation patterns.[4-5]
- Combination of pressure-sensitive mat and IR thermal camera has not been investigated as a method to monitor PU development

OBJECTIVE

To explore the roles of immobility and vascular changes in the development of lower limb pressure ulcers in Complex Continuing Care (CCC) patients, using two sensor technologies; the pressure-sensitive mat and the IR thermal camera (Figure 1.)

METHODS

- Observational pilot study at Saint-Vincent Hospital, part of Bruyère Continuing Care in Ottawa.
- Total of 7 participants at high-risk for pressure ulcers
- Technology used as adjunct to usual clinical care
- Primary outcomes:
  - Presence or absence of pressure ulcer
  - Continuous pressure (mats)
  - Blood circulation (IR thermal camera)
- Fiber-optic based, pressure-sensitive mat (S4 Sensors Inc.) placed under the mattress below the feet
- IR camera (FLIR Systems Inc.) used to capture morning heel skin temperature bi-weekly
- Mat data collected 24/7 and converted to mean sum of pressures (SoP) and standard deviation (StDev)

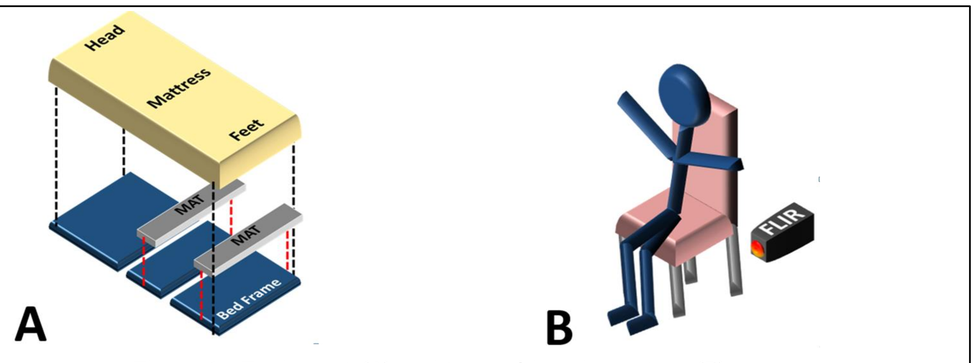

Figure 1. Equipment (A) and thermal imaging set-up (B)

Figure 1. A fiber-optic based, pressure-sensitive mat (S4 Sensors Inc.) was placed under the mattress below the feet while an IR camera (FLIR Systems Inc.) was used to capture morning skin temperature at the heels.

RESULTS

- Preliminary results from one patient obtained
- 64-year old female with stroke, dialysis, high risk of PU development (MDS 2.0 – Pressure Ulcer Risk Scale score: 6)
- Data collected over 120 days
- The morning of August 12th, 2015: skin temperature over the L heel lower than the R heel (26 C vs. 28 C)
- Corresponding mat data showed a larger SoP and lower StDev

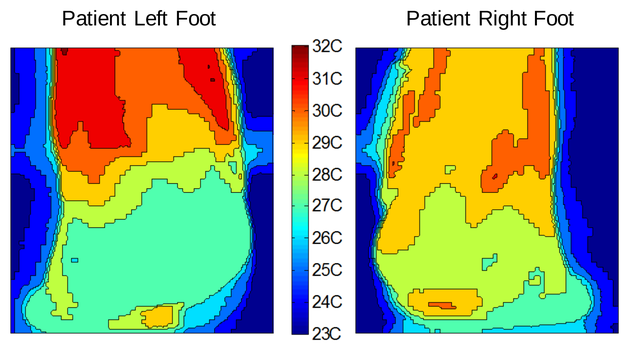

Figure 2. Contour plots of the patient 's heels and corresponding temperature (C°)

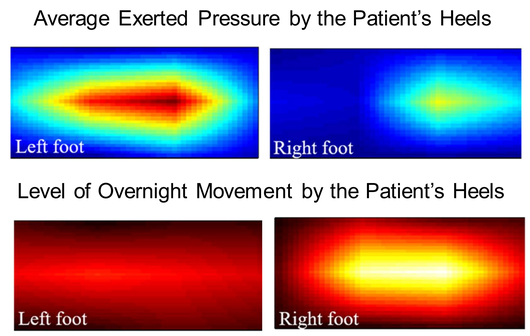

Figure 3. Average exerted pressure and level of overnight movement at the heels

Figure 2: The thermal images were transformed into heat maps by calculating contours representative of each 1°C between the temperature range of 23°C to 32°C, as well as the area of skin (measured by number of pixels) at these specified temperatures.

Figure 3: Average exerted pressure by the patient's heels and level of overnight movement by the patient's heels, for one night (9pm - 8am).

DISCUSSION

- There is a correlation between reduced mobility (mat pressure) and reduced skin temperature (IR images).
- We believe that this is the first time these 2 sensors have been combined to show the link between limb mobility and micro-vascular circulation.
- Our next step is to complete analyses on all 7 participants.
- Sensor-based technologies may provide an early indication that they are a viable, low-cost, low-risk, and unobtrusive method for skin monitoring in various health care settings.
- Broader studies as well as randomized controlled trials are needed to confirm the effectiveness of using these technologies for monitoring skin integrity.

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REFERENCES

1) Coleman S, Gorecki C, Nelson EA et al. (2013). Patient risk factors for pressure ulcer development: Systematic review. International Journal of Nursing Studies, 50: 974-1003.
2) Woodbury MG, Houghton PE. Prevalence of pressure ulcers in Canadian healthcare settings. *Ostomy Wound Manage*. 2004;50(10): 22-4, 26, 28, 30, 32, 34, 36-8.
3) Chan B, Ieraci L, Mitsakakis N, Pham B, Krahn M. Net costs of hospital-acquired and pre-admission PUs among older people hospitalised in Ontario. *J Wound Care*. 2013;22(7):341-2, 344-6
4) Barnett, R. I., & Ablarde, J. A. (1995). Skin vascular reaction to short durations of normal seating. Archives of physical medicine and rehabilitation, 76(6): 533-540.
5) Lahiri, B. B., Bagavathiappan, S., Jayakumar, T., & Philip, J. (2012). Medical applications of infrared thermography: a review. Infrared Physics & Technology, 55(4): 221-235.