Electrical Stimulation in Combating Pressure Ulcer for Immobilize Subjects: A Conceptual Framework

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Abstract. A paradigm shift in health system did intensify the need for research on wearable electronics. There are numerous reasons that could lead to skin ulcers. The most common are lesion due to constant pressure, incontinence control, excessive humidity and postural changes. Over the years, there have been numerous interventions ranging from specific skin treatment, introducing prevention programs as well as to mechanical intervention. On the rise in such clinical rehabilitation program is the use of electrical stimulation (ES) at a therapeutic level, wound care and muscle function restoration. This paper presents a concept development and implementation process of a new pressure ulcer intervention system which can be used for both chairbound and bedridden patients. The concept here is to integrate the use of electrical stimulation, interface pressure mapping and redistribution with antimicrobial protection not only to act as therapeutic but at the same time as a means of prevention of pressure ulcers by improving muscle tone and decreasing atrophy among immobilized subjects.

1. Introduction

It is but a common medical knowledge today how devastating Pressure Ulcer (PU) could be mostly on immobilized subject. Usually, PU development occurs in subjects when the interface pressure rises above 32 mmHg for an extended period roughly within 2 - 6 hours without timely relief [1]. Although PU pathophysiology has been extensively mapped out and readily available, over the years there have been little to no reports on the reduction in PU prevalence [2]. Similarly, PU diagnosis, treatment and management are classified as a national burden in developed nations, thus one can only imagine the case for developing or underdeveloped ones? [1-3]. As shown in Figure 1, a summary of literature and practice consensus for prevention and management of PU cases can be coined under the acronym S.K.I.N. Keeping proper Diet and Nutrition as constant, any or a combination of this key procedure along with some tailored PU risk assessment tools are mostly employed in today’s PU intervention system.
A deeper look into the acronym S.K.I.N. where:

S: represent the stimulation of human skin,
K: represent the keen observation,
I: represent the interface pressure,
N: represent the neutralization of microorganism.

Therefore, a holistic Pressure Ulcer Prevention and Management System (PrUPMIS), options under skin stimulation would include but not limited to the use of electrical or mechanical stimulation. A keen observation would be maintained either via constant pressure mapping or visually monitoring skin condition. Other factors would include interface pressure unloading or redistribution process, the neutralization of microorganism achieved with proper humidity control and efficient wound care. When these parameters are merged, a holistic PU system can thus be guaranteed.

Table 1 thus provides highlights of selected innovations which can be integrated into a PU management scheme while Table 2 is more on PU dedicated devices some readily available while others are still undergoing clinical testing. It is thus evident from the innovation or devices in Table 1 and Table 2 that none of them could provide a combination of all the S.K.I.N features on a single device system thus the deficiency in combating PU prevalence.

**Table 1.** Selective highlight on Pressure Ulcer relative innovations [4-7].

| Product | Company | inventors/Conceived by | Technology | Strength | Weakness/Limitation |
|---------|---------|------------------------|------------|----------|--------------------|
| CONFORMat™ & BPMS™ | Tekscan, Inc | Tekscan, Inc | Thin-film sensor (resistive), 2D & 3D data, USB, WLAN | 1 Sensel/cm², 195.07 x 42.67 [cm], 8,064 sensors, | PU intervention only on pressure redistribution |
| ForeSite PT ™ | XSENSOR Technology Corporation | XSENSOR Technology Corporation | Capacitive Pressure Sensor, Disinfectable mattress cover, 2D & 3D data, Bluetooth & WLAN | 30” x 74”, 52 x 118 Sensor Array @ 0.625” by 1mmHg Res; 6000 flex sensors, | PU intervention only on pressure redistribution |
| Mattress Mat & Seating Mat | Sensing.Tex(R) | Miguel Ridao Granado; Luis Miguel Gomez Anta; Elkin Diaz Garzon; Francisco Paredes Rivas | Textile Sensor, Electronic Ink and Paste Materials, a resistive sensor, Bluetooth & USB | 85 x 190 [cm], 1152 sensor points, stretchable textile, customizable with SDK kit | PU intervention only on pressure redistribution |
| SmartMat | Performance Research, Inc | Mazir Sadri; Amy Lombardo; Max Bodhisuwan; Paul Hodgson; Leanne Beesley; Chris Gormley | Piezoresistive sensor, Bluetooth Interface (iOS & Android), PVC | 71”x26”, 21000 sensor, water resistance, withstand 110F heat, non-invasive sensors | Not designed for PU intervention |
Looking back at PU pathophysiology and human anatomy, people with severe motor limitations (immobility) mostly have a decreased sensitivity in their body areas in contact with the respective support surfaces, hence are more at risk of developing PU while doing the same actions (sitting for 2-6hrs) compared to their counterparts who had either knowingly or subconsciously fidget to relief interface pressure from time to time [8,10].

The National Pressure Ulcer Advisory Panel (NPUAP), European Pressure Ulcer Advisory Panel (EPUAP) and Pan Pacific Pressure Injury Alliance (PPPIA) in her most recent report, Prevention and Treatment of Pressure Ulcers: Quick Reference Guide; compiling extensive research with evidence of common preventive strategies and new innovation in the field of combating PU menace to formulate more effective guidelines and point out evidence-based direction where further research is required such as modalities for electrical stimulation in PU cases [1].

This integration and Implementation of Electrical stimulation are expected to be used for mimicking the natural fidgeting movements that people with healthy nervous systems perform subconsciously to alleviate discomfort, improve blood flow, which helps to keep soft tissues healthy while sitting or sleeping for extended periods [1-3,8].

Since an Effective PU prevention starts with risk identification and nutritional assessment, followed by the implementation of support surfaces, prophylactic dressings, and repositioning regimens for appropriate patients. A multidisciplinary patient-centered approach is always encouraged for PU management [11]. Hence, we present a concept architecture for PU intervention system (see section 2) that integrates active pressure mapping, electrical stimulation with antimicrobial inhibition on a fabric overlay to achieve a holistic yet cost-effective solution to PU cases.

### Table 2. Selective highlight on Pressure Ulcer innovations. [8-9, 3, 10-11]

| Product            | Company                                      | inventors/Conceived by | Technology                          | Strength                                      | Weakness/Limitation                                      | Corresponding Author                                      |
|--------------------|----------------------------------------------|-------------------------|-------------------------------------|-----------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|
| SEM Scanner™      | Bruin Biometrics, LLC                        | Barbara Bates-Jensen    | Bioimpedance (tissue capacitance)   | 3-10 day early detection prior to physical changes; high accuracy, Denert DTI and PU, non-invasive | PU intervention only on early detection of Risk Marker (SEM) | Corresponding Author                                      |
| Pro-TECT™         | Coulter Translational Research Partners Program, Uni. Pittsburgh | David Brienza, Alan Mundock | Measurement of Sub epidermal moisture | Embedded Colling elements with adjustable dry air redistributive pressure overlay design. | PU Intervention only at fixed assume high-risk target area. | Corresponding Author                                      |
| Project ActiveRest| FEDER funds through the COMPETE 2020 Programme | Pereira S., Fonseca J., Almeida J., Carvalho R., Pereira P. and Simoes R | ROHOTM dry Flotation overlay with embedded Targeted Colling element (gel cushion for SCSCP) | Pressure sensing and monitoring system and can be integrated with an actuation system. | Developmental phase                                      | Corresponding Author                                      |
| Smart-e-Pants     | Alberta Innovates Health Solutions & Prev Biotech, Inc | Vivian Mushahwar and team. | Commercial piezoresistive sensors (FSR) embedded in a textile substrate | Easy to use and reuse, mild stimulation mimicking fidgeting to prevent PU and increase blood flow. | Clinical trial phase                                     | Corresponding Author                                      |
| PrUPMIS (Proposed)| IIUM RMC under MESTECC Research Grant        |                         | Electro-Stimulator, fabric electrodes and anti-bacterial garment | Holistic PU intervention, non-invasive, easy adoption, rapid prototyping cost reduction. | Development phase                                       | Corresponding Author                                      |
2. System overview

In order to design a holistic system for PU management, major factors to be considered in such system are its ability to conduct skin-risk assessment and reassessments, manage moisture, minimize mechanical stress (pressure, share and friction) and create a patient, family or caregiver easy access of engagement without physically discomforting either. The novel solution proposed here is thus seen in Figure 2 where real-time active pressure mapping is systemically combined with electrical stimulation.

![Figure 2. Proposed System architecture](image)

As shown in Figure 2, The proposed system is subdivided into 4 major blocks consisting of an external electrical stimulator device, a fabric mat which an array of electrode is printed on using proprietary conductive inks with antimicrobial properties, a microcontroller block for signal generation, processing and control and finally a communication channel where processed signals are displayed for instant and post-processing. The electrodes embedded in the fabric mat are done systematically to provide both tactile properties for constant pressure mapping and stimulation terminals for the external electrical stimulator signal. Following a specified algorithm uploaded into the microprocessor, the device constantly measures interface pressure for a predefined threshold. Once this value is meet, the electrical stimulator is activated thereby sending stimuli pulse to the localized area above the preset pressure threshold. This ensures a continuous cycle of pressure relief and skin stimulation, improve blood flow, increase muscle tone and decrease atrophy. Similarly, due to the fabric material of the mat and the antimicrobial properties of the collective electrode array, moisture and microbes are easily controlled hence preventing the development or further regression of PU cases.

3. Conclusion

It can be imagined as it still puzzles the public that despite the advances in biotech, medicine, and related research, the prevalence of Pressure Ulcer both in and out of the hospital patients are alarming both in cost and labour hours put into its management and the quality of life of such patients. Hence, we concluded from our related survey of PU reports comprising of clinical research, nursing home reports, Pressure Ulcer Advisory Panels guides and the major problem that stood out in Combating PU cases is the lack of holistic solution rather the focus on specificity in an aspect as shown in Figure 1. Hence, this research proposes yet a novel approach that encompasses existing sparse solution into a single system with a device that would not only reduce costs but also save caregivers work time and as well improve the quality of life in PU patients most especially the at-risk Immobilize categories. Future reports would include the developmental process, procedure, test and benchmarking.

Acknowledgments

This research is fully sponsored under the Malaysian Ministry of Energy, Science, Technology, Environment and Climate Change (eScienceFund Project No. 06-01-08-SF0324).
References

[1] National Pressure Ulcer Advisory Panel, European Pressure Ulcer Advisory Panel and Pan-Pacific Pressure Injury Alliance 2014 *Prevention and Treatment of Pressure Ulcers: Quick Reference Guide* ed Emily Haesler (Osborne Park, Western Australia: Cambridge Media)

[2] Tran J P, McLaughlin J M, Li R T and Phillips L G 2016 *J. American Society of Plastic Surgeons: Plastic and Reconstructive Surgery*, **138**(3S), 232S–40S.

[3] Pereira S, Fonseca J, Almeida J, Carvalho R, Pereira P and Simoes R 2019 *Proc. 12th Int. Joint Conf. on Biomedical Engineering Systems and Technologies* 22-24 Feb. 2019 Prague, Czech Republic Vol 1 p 291-6.

[4] Tekscan™ *Body Pressure Distribution | Body Pressure Measurement System (BPMS) - Research* https://www.tekscan.com/products-solutions/systems/body-pressure-measurement-system-bpms-research (accessed April 14, 2019)

[5] Wong H, Kaufman J, Baylis B, Conly J M, Hogan D B, Stelfox H T, Southern D A, Ghali W A and Ho C H 2015 Efficacy of a pressure-sensing mattress cover system for reducing interface pressure: Study protocol for a randomized controlled trial *Trials* **16** 434.

[6] Sensing.Tex Bedding Mat Platform - Sensing Tex Pressure Mapping (n.d.). http://sensingtex.com/sensing-mats/mattress-mat/ (accessed April 14, 2019)

[7] INDIEGOGO *SmartMat: The World’s First Intelligent Yoga Mat* https://www.indiegogo.com/projects/smartmat-the-world-s-first-intelligent-yoga-mat#/ (accessed April 15, 2019)

[8] Bates-Jensen B M, McCreath H E and Patlan A 2017 Subepidermal moisture detection of pressure-induced tissue damage on the trunk: The pressure ulcer detection study outcomes *Wound Repair and Regeneration*, **25**(3) 502–11

[9] Brienza D, Murdock A 2014 *Pro-TECT: Mattress overlay to prevent pressure ulcers*, Coulter Transl. Res. Partners II Program, Univ. Pittsburgh.

[10] Topfer L A 2015 Smart-e-Pants: Using Intermittent Electrical Stimulation to Prevent Pressure Ulcers *Issues in emerging health technologies*, Issue 132 (Ottawa: Canadian Agency for Drugs and Technologies in Health)

[11] Fajingbesi F E, Azman A W, Olanrewaju R F, Ahmad Z, Mustafah Y M 2019 A Glimpse at Functional Electrical Stimulation for Combating Pressure Ulcers in Immobilize Subjects *Late Breaking IFESS Poster at RehabWeek2019* 25-28 June 2019 Toronto Canada.