TECHNOLOGY ADVANCES

WHS Wound Healing Society

Visual Feedback of Continuous Bedside Pressure Mapping to Optimize Effective Patient Repositioning

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Objective: To evaluate the effectiveness of a new bedside pressure mapping technology for patient repositioning in a long-term acute care hospital.

Approach: Bedside caregivers repositioned patients to the best of their abilities, using pillows and positioning aids without the visual feedback from a continuous bedside pressure mapping (CBPM) system. Once positioned, caregivers were shown the image from the CBPM system and allowed to make further adjustments to the patient position. Data from the CBPM device, in the form of visual screenshots and peak pressure values, were obtained after each repositioning phase. Caregivers provided feedback on repositioning with and without the CBPM system.

Results: Screenshots displayed lower pressures when the visual feedback from the CBPM systems was utilized by caregivers. Lower peak pressure measurements were also evident when caregivers utilized the image from the CBPM systems. Overall, caregivers felt the system enabled more effective patient positioning and increased the quality of care they provided their patients.

Innovation: This is the first bedside pressure mapping device to be continuously used in a clinical setting to provide caregivers and patients visual, instant feedback of pressure, thereby enhancing repositioning and offloading practices.

Conclusion: With the visual feedback from the pressure mapping systems, caregivers were able to more effectively reposition patients, decreasing exposure to damaging high pressures.

INTRODUCTION

Pressure ulcers remain at the top of the list of preventable events occurring in hospitals each year.[1] Despite prevention efforts, pressure ulcers still occur within hospitals and healthcare facilities, often leading to detrimental outcomes. It has been estimated that worldwide over 7.4 million patients have pressure ulcers. In U.S. hospitals, 2.5 million pressure ulcers are treated each year. Total expenditures for treating pressure ulcers have been reported to exceed $11 billion each year. A recent retrospective analysis of Medicare patients discovered those who developed pressure ulcers while in hospitals were more likely to die during their hospitalization, remain in the hospital for an average of 6.4 days longer than those who did not acquire a pressure ulcer, and were more likely to be readmitted to the hospital within 30 days of being discharged.[2] Development of a pressure ulcer is reported to increase mortality rates by 7.23%.[3] Sixty thousand deaths per year have been associated with pressure ulcers.[3] Even with

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current guidelines and interventions, pressure ulcers remain a sizable problem affecting the quality of life for millions of patients and placing large burdens on our healthcare systems.

In long-term acute care hospitals (LTACHs), where sixty-three percent (63%) of the population is known to be at risk for pressure ulcer development, prevalence of pressure ulcers has been reported at 27.3%, of which 8.5% are facility-acquired.[4] One out of every four patients in a LTACH has a stage II or higher pressure ulcer.[4] In this very high-risk population, extensive medical interventions further challenge caregivers interfering with regular turning schedules and standard offloading practices.

To assist caregivers in preventing pressure ulcers, the National Pressure Ulcer Advisory Panel (NPUAP) has published guidelines stating that repositioning is important to reduce the magnitude and duration of pressure over vulnerable areas of patients' bodies.[5] Reducing the amount of time and intensity of pressure that patients are exposed to lessens the risk of developing a pressure ulcer.[5] Using appropriate support surfaces and repositioning techniques are recommended.[5] Techniques suggested for proper positioning include using a 30° side-lying position, instead of 90°, and avoiding head of bed elevation above 30°.[5] Using best clinical judgment for each individual patient is key when following the guideline to reposition a patient in such a way that pressure is relieved or redistributed.[5]

These guidelines beg the following questions:

1. How do caregivers know that patients are repositioned in such a way that pressure has been relieved or redistributed?
2. How do caregivers know that the duration and magnitude of pressure over vulnerable areas of the body have been reduced?
3. How do caregivers know that prescribed support surfaces are adequately reducing pressure over vulnerable areas of the body?
4. How do caregivers know that prescribed support surfaces are functioning correctly?

A recent study by Petersen, etal. discovered that healthcare providers are unaware of the actual pressure-relieving or reducing effectiveness of their repositioning intervention, or lack thereof.[6] The authors also observed that patients at high risk for pressure ulcer development exhibit high skin-bed interface pressures specifically over areas likely to be in jeopardy despite routine repositioning care.[6] Relieving or reducing pressure to at-risk tissue is a necessity for pressure ulcer prevention. If repositioning techniques are not effective, then patients continue to be at high risk for tissue breakdown, which may also explain why repositioning strategies are not always successful.[6] Pressure mapping and monitoring could be used to develop better patient repositioning techniques.[6] In this study, a pressure mapping and monitoring device was utilized in a clinical setting to attempt to understand its affects on the intervention of repositioning.

CLINICAL PROBLEM ASSESSED

Monitoring has become a standard practice in preventative strategies for many diseases and conditions. Without monitors many early warning signs are missed. Without monitoring, timely treatment is not possible and poor outcomes ensue. Cardiac monitoring is used to determine the cause of palpitations and syncope and to identify ventricular ectopy or nonsustained ventricular tachycardia in patients at potential risk for sudden cardiac death or myocardial infarctions. Atrial fibrillation is an increasingly important indication for ambulatory monitoring, predominantly as a tool to monitor the efficacy and safety of pharmacological and nonpharmacological therapies.[7]

Unlike life-threatening cardiac events, where a heart monitor may detect early changes in electrical activity before the first physical symptoms are noted,[8] caregivers have not had a dynamic real-time monitor to assess the potentially damaging pressures that can exist between patients and support surfaces. The one-time use of a pressure mapping device to identify areas where a patient may be vulnerable to developing a pressure ulcer (as is currently the practice) provides only a "snapshot" at one moment in time. After the assessment is completed and the patient is removed from the device, the only way to assess where potential pressure damage exists is subsequent observation of tissue damage.

Knowing that pressure over time is the main causative agent of a pressure ulcer, a prevention program would benefit from a way to continuously monitor the pressure beneath patients. The need for individualized monitoring is necessary, due to variations in patient body type and presenting comorbidities for pressure ulcer development. Continuous bedside pressure monitoring (CBPM) enables caregivers to make informed assessments in real time and institute protective measures in a timely fashion.

Currently, in lieu of monitoring, pressure ulcer risk is identified through risk assessment scores, such as a Braden Score.[9] However, 58% of patients who developed a hospital-acquired pressure ulcer (HAPU) were only assessed at mild or moderate risk on the risk assessment scale, whereas only 5.1% of patients who scored at a very high risk developed a HAPU.[3] Daily skin assessments are another way caregivers assess high pressure areas, looking for skin that has already become reddened. However, once redness is observed, deeper tissue damage may have already begun. Gefen reports that most cell death from pressure occurred between 1 and 4 h postloading and higher tissue deformations from pressure led to faster tissue damage.[10] This is consistent with the Reswick and Rogers finding that pressures exceeding diastolic pressure can cause ulcer development in 6 h, whereas pressure exceeding systolic can cause damage in less than 1 h.[11] Therefore, the higher the peak pressures patients are exposed to, the faster they are to likely develop tissue damage.

Currently, patients are repositioned in bed without any feedback confirming that the positioning is effective. One recommended position is the 30° tilted side-lying position.[4] A recent review by the Agency for Healthcare Research and Quality (AHRQ) found that in two of three reviewed studies patients could not tolerate the 30° tilt position for the intended amount of time.[12] Patients who are unable to tolerate these recommended positions must be repositioned "blindly" without benefit of recommended best practices.

Moreover, many patients and their families do not understand the importance of offloading pressure and repositioning. In the absence of protective sensation, patients are unaware of potential tissue damage and have no impetus to change position. With a CBPM, patients can see where damaging pressures exist and reposition themselves or have caregivers effectively reposition them. The monitor serves as an educational tool for patients and families helping them to understand where pressures are posing a potential threat. Increased compliance with positioning schedules may ensue as patients and families take an active, informed role in their own care.

MATERIALS AND METHODS

A long-term acute care facility outfitted specialty air and air-foam combination beds with continuous bedside pressure mapping (CBPM) systems (M.A.P™, Wellsense USA, Inc., Nashville, TN; Fig. 1). CBPM systems attach to existing mattresses and continuously monitor pressures beneath the patient (Fig. 1B). The monitor attached to the pressure-sensing mat displays low pressures as blues and greens and higher pressures as oranges and reds, analogous to severity systems used on weather map displays (Fig. 1C). The pressure readings are taken twice a second and updated on the monitor in near real time.

Ten patients identified as high risk for pressure ulcer development (Braden ≤ 12) had CBPM systems placed beneath them. Data were collected at repositioning times prescribed by hospital procedures. Initially the images from the CBPM systems were not made available to the caregivers. Three caregivers were asked to reposition patients to the best of their abilities, using their usual techniques (pillows, positioning aids, *etc*.). Two caregivers positioned three patients each, and the third caregiver positioned four patients. Pressure images from screenshots and peak pressure measurements were blindly recorded.

Caregivers were then shown the image from the CBPM device and asked whether they wanted to make any changes. Pressure images from screenshots and peak pressure measurements were recorded a second time.

Caregivers were not matched with patients for whom they were actively caring, to eliminate any bias of knowing how to position the patient based on a prior experience. Caregivers were given as much time as they wanted to position and reposition patients. Images and peak pressures were recorded after the caregivers had completed the repositioning phase.

Caregivers who utilized the CBPM systems were anonymously surveyed for feedback pertaining to ease of use, effectiveness, and quality of care.

RESULTS

Screenshots displayed lower pressure images and measured pressures were decreased when caregivers utilized the CBPM system (Fig. 2A–D). A greater amount of blues and greens, signifying lower pressures, were present when the caregivers utilized the image from the CBPM systems to assist repositioning. The average peak pressure without the CBPM image was 78 mmHg, ranging from 48 to 107 mmHg. When using the CBPM images, peak pressures averaged 47 mmHg, ranging from 33 to 60 mmHg. The average peak pressure reduction for the ten repositions was 31 mmHg (Fig. 3).

Most caregivers elected to turn the patient to a side. However, three patients were unable to be fully turned due to complex medical conditions. These patients remained in the supine position. Caregivers initially attempted to reposition these

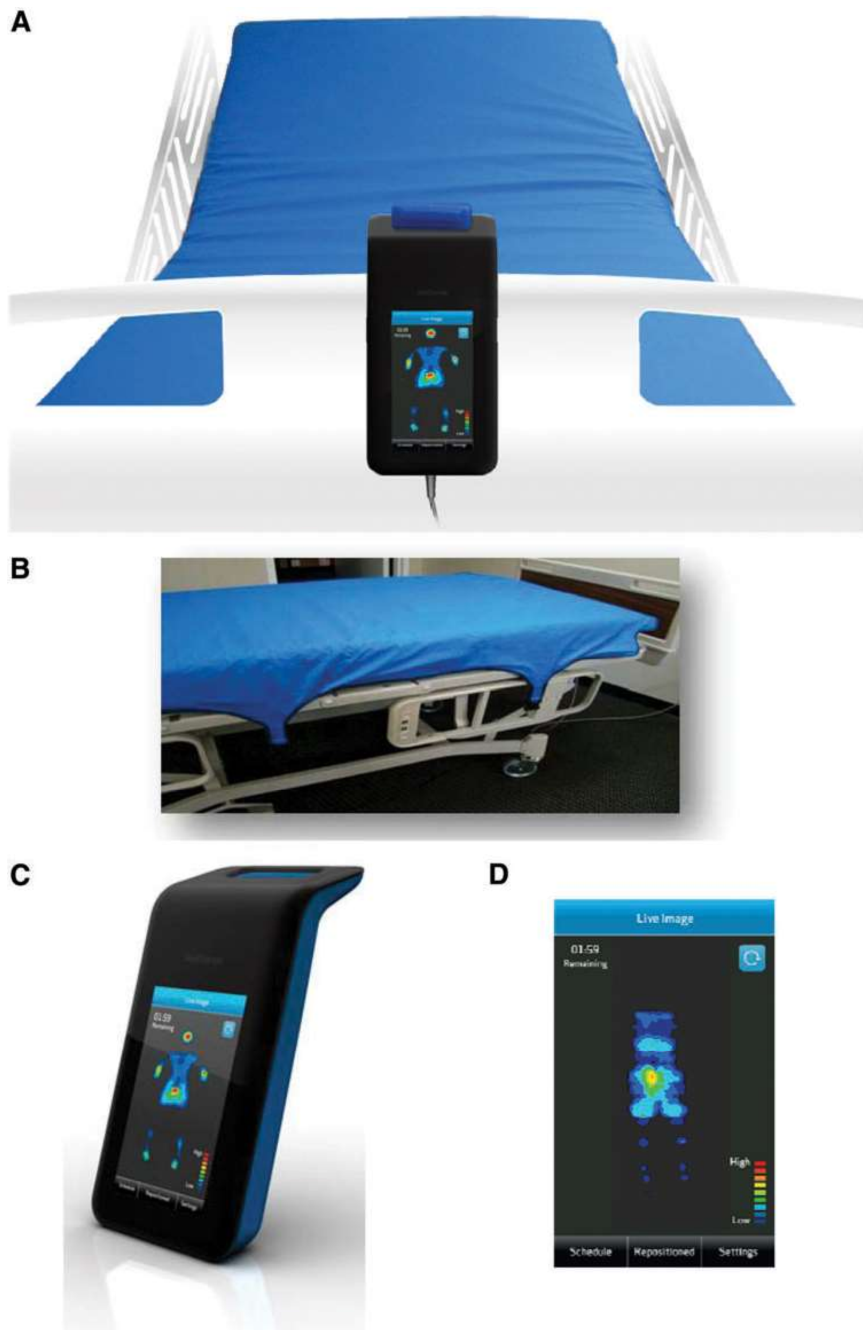

Figure 1. M.A.P™ System by Wellsense USA, Inc. **(A)** The continuous bedside pressure mapping system attaches to an existing mattress. **(B)** Pressure sensing mat. **(C, D)** Monitor displaying real-time pressure image. Variations in pressure are displayed using a color scheme where red indicates high pressure and blue indicates low pressure.

patients with small adjustments from supine, and then readjusted them using the CBPM image. These small adjustments, allowed the caregivers to lower the peak pressures even in these medically complex patients (Fig. 2C,D). Patient #6 had peak pressures reduced from 74 to 45 mmHg despite these seemingly small adjustments.

One patient insisted she remain on a bedpan for long periods of time. CBPM displayed a peak pressure of 107 mmHg (Fig. 2E), and high

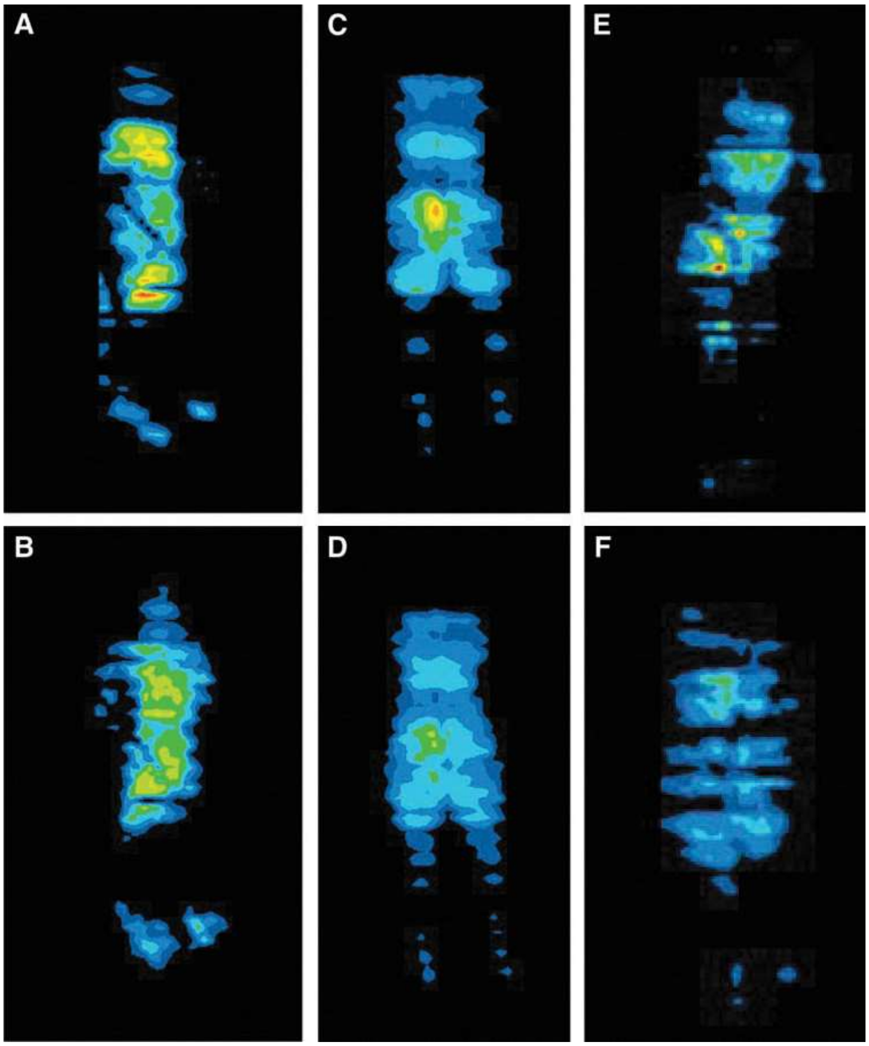

Figure 2. Patients #1 **(A, B)** and #6 **(C, D)**, positioned without utilization of the pressure image **(A, C)** and utilizing the image from the pressure monitor **(B, D)**. **(E)** Bedpan beneath patient. **(F)** Bedpan no longer beneath patient.

pressures as seen by red, orange, and yellow on the screenshot image. When the bedpan was removed peak pressures were decreased to 42 mmHg (Fig. 2F). Lower pressures were evidenced by blues and greens on the monitor's image. This observation reflects the high pressures iatrogenic foreign bodies create beneath patients.

One hundred percent of the caregivers surveyed agreed that they were more effective in repositioning patients with the use of the pressure map image versus without the image. They all also felt that CBPM increased the quality of care they were able to give their patients. Caregivers found the CBPM systems easy to use and reported that families and patients were less likely to refuse repositioning and turning because they could now visualize and comprehend the high pressures depicted by the monitor.

DISCUSSION

High or peak pressures can have the most detrimental effect on tissue. As Gefen reports, higher tissue deformations lead to earlier initiation of tissue damage.[10] Therefore, identifying these high pressures, intervening with effective repositioning to alleviate them, and continuous monitoring is essential for a pressure ulcer prevention program.

The use of offloading surfaces and patient repositioning is standard of care in the prevention

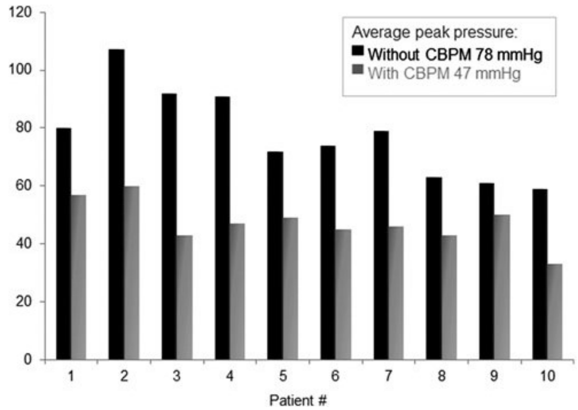

Figure 3. Peak pressures without and with utilization of the monitors images.

and treatment of pressure ulcers.[5] This study shows that blind repositioning alone may be ineffective in reducing peak pressures that lead to pressure ulcer formation. This is consistent with the findings of the Petersen study where patients were found to exhibit high interface pressures despite routine repositioning care.[6] The use of real-time pressure sensing technology in concert with therapeutic support surfaces and effective repositioning enhances pressure reduction and results in improved patient safety and outcomes.[13]

The visual feedback from the CBPM systems gave caregivers an effective guide to reposition patients. The utilization of real-time color images, to guide interventions played an important role in minimizing pressure under bedbound patients. Current techniques, such as the 30° side-lying position, have been shown to decrease pressures beneath patients. In patients who could not tolerate this position, CBPM systems provided guidance for effective repositioning. CBPM was readily accepted by staff, family, and patients.

Real-time monitoring is an integral tool in the timely assessment and treatment of many diseases. Many life-threatening conditions are converted and managed by effective and timely monitoring. Pressure mapping and monitoring is a noninvasive way to measure and monitor pressures applied to the skin.[6] Skin pressures do not directly correlate to deeper pressures on tissues or capillary pressure.[6] However, being able to assess and monitor where external pressure is being applied to the skin gives healthcare providers the opportunity to lower high peak pressures, which lowers the external pressure that is applied to tissue and decreases the possibility of pressure ulcer development.[6]

KEY FINDINGS

- This new CBPM monitor enables caregivers and patients to visualize, assess, and monitor pressure points between the patient and the support surface
- With visual feedback caregivers decrease peak pressures beneath patients through more effective repositioning
- Utilizing CBPM may show promise in decreasing the occurrence of HAPU in high-risk patient populations

The current state of care uses pressure mapping systems only for assessment and measurement in a static part of a care model. Static assessment often only reveals a problem after tissue damage has occurred. This study shows CBPM is a promising technology used at the bedside that could enhance pressure ulcer care and prevention through early detection and guided care. A recently published retrospective trial reported a statistically significant reduction in HAPU when CBPM was incorporated into the pressure ulcer prevention program.[13] Additional controlled trials are needed to validate how monitoring directly affects the incidence of pressure ulcers. CBPM appears to be a safe, effective, and dynamic monitoring system. CBPM may have a place in the broader efforts to reduce HAPU.

INNOVATION

M.A.P™'s pressure sensing mat (Fig. 1B) is made of an intelligent textile, which constantly measures pressure from thousands of discrete points. The variations in pressure across a patient's body are depicted on a handheld monitor (Fig. 1C), using a color scheme to help caregivers visualize high (red) to low (blue) pressure points (Fig. 1D). This system allows them to easily identify and minimize areas of high pressure. M.A.P™'s live, color feedback empowers caregivers to easily identify early warning signs of high pressure and potential risk to patient safety. M.A.P™ has demonstrated a statistical significance in improving a facility's pressure ulcer prevention program.[13]

AUTHOR DISCLOSURE AND GHOSTWRITING

R.G.S. discloses that he is a Medical Advisor for Wellsense USA, Inc. K.M.T. discloses that she is the Director of Clinical Services for Wellsense USA, Inc. The content of this article was expressly written by the authors listed. No ghostwriters were used to write this article.

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Abbreviations Used

AHRQ = Agency for Healthcare Research and Quality
CBPM = Continuous Bedside Pressure Mapping
HAPUs = Hospital-Acquired Pressure Ulcers
LTACH = Long-Term Acute Care Hospital
NPUAP = National Pressure Ulcer Advisory Panel