Update on Pressure Injuries: A Review of the Literature

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CME 1 AMA PRA Category 1 Credit™
CE ANCC 1.5 Contact Hours

GENERAL PURPOSE: To provide information about the latest evidence-based practice related to pressure injuries (PIs).
TARGET AUDIENCE: This continuing education activity is intended for physicians, physician assistants, nurse practitioners, and nurses with an interest in skin and wound care.
LEARNING OBJECTIVES/OUTCOMES: After participating in this educational activity, the participant should be better able to:
1. Identify risk factors and prevention strategies for PI.
2. Explain issues related to the treatment of PI.

ABSTRACT
The literature on pressure injuries continues to expand at a rapid rate, and keeping up to date with the current knowledge base is challenging. This summary describes six important new articles published in 2018 or 2019 about pressure injury pathophysiology, prevention, treatment, and epidemiology. For each article, a description of the results is provided, and then a comment about the significance of the results is offered. The new knowledge contained in this review should impact how clinicians incorporate the latest evidence-based practice for pressure injuries.
KEYWORDS: cost-effectiveness, epidemiology, pathophysiology, patient safety, pressure injury, prevention, treatment

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INTRODUCTION

The literature on pressure injuries continues to grow. A recent PubMed search using the terms *pressure ulcer* or *pressure injury* and limited to 2018 yielded more than 550 citations. For busy clinicians, keeping up with this volume of literature is nearly impossible. In this article, the authors review six pressure injury articles from 2018 and 2019.

Articles were selected by the authors based on their perceived relevance to clinical practice. The articles are not necessarily the six "best" articles from the past 2 years, but rather represent important additions to the field in the view of the authors. Each month, a medical librarian provided the authors with a list of newly published pressure injury articles. One author would review these lists and select potential articles for discussion with the other author. Additional input on important recent articles was sought from National Pressure Injury Advisory Panel members involved in the update of the pressure injury guideline.

Articles were selected from the English literature to represent a range of topics including pressure injury pathophysiology, prevention, treatment, and epidemiology. Articles were not limited to original research; the authors also considered insightful reviews and syntheses of data. To avoid potential bias in article selection, the authors avoided articles they coauthored or that were published in this journal, *Advances in Skin & Wound Care*.

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For each article, the authors first provide the reference in bold text. Next, the key findings from the article are summarized. Finally, comments are offered about why and how this article is important or impactful for clinicians.

ARTICLE 1

Kottner J, Black J, Call E, Gefen A, Santamaria N. Microclimate: a critical review in the context of pressure ulcer prevention. Clin Biomech (Bristol, Avon) 2018;59:62-70.

This article reviews the causes of pressure injuries and recommendations for prevention as they relate to microclimate. The microclimate consists of the temperature, humidity, and airflow proximal to the skin surface. The stratum corneum, as the outermost layer of the epidermis, provides the boundary between the humid and warm interior and the dry and cold exterior of the body. Therefore, the stratum corneum is the first layer directly affected by microclimate changes, which in turn affect the underlying epidermal and dermal cells.

There are complex interactions between temperature and moisture. Hydration of the stratum corneum varies with microclimate humidity. Overhydration results in a decrease in stratum corneum stiffness and mechanical strength, whereas dry skin is associated with increased stiffness and cracking of skin. Moreover, both over- and underhydration of skin increase the coefficient of friction such that skin is more adherent to its contact surface. This results in greater deformation and shear forces being transmitted to the subcutaneous tissues. Higher skin temperatures are transferred to deeper tissue layers, including muscle, and impaired skin perfusion from pressure prevents dissipation of local heat. With higher tissue temperatures, there is a greater likelihood and increased severity of pressure injuries.

Keeping skin cool and dry is good clinical practice and may be assisted by low-air loss and air-fluidized beds. Occlusive materials including clothing, linens, and some dressings may disrupt heat and moisture transfer at the skin surface. Less occlusive coverings promote the skin's ability to evaporate humidity and decrease harmful effects from changes in microclimate. Avoid microclimate extremes to prevent deformation of the skin surface and reduce the likelihood of pressure injury development.

Comment

Classic teaching always was that pressure injuries (known in those days as pressure sores or even decubiti) were the result of four external factors: pressure, shear, friction, and moisture.[1] Pressures above the capillary arteriolar pressure of 32 mm Hg may result in the occlusion of blood vessels with resulting tissue ischemia and death.[1] Despite this, clinicians have always been a little uncomfortable with this formulation, especially for stage 3 and 4 pressure injuries. How can something like superficial moisture result in tissue ischemia and cell death in the deep muscles where severe pressure injuries are likely to develop?[2]

The conceptual understanding of how pressure injuries develop has since advanced considerably.[3] We know that poor perfusion, as seen with sepsis or peripheral arterial disease, is an important contributor to tissue ischemia. It is not only ischemia that leads to cell death, but also the deformation of muscle cells near bony prominences that can cause tissue necrosis.[4] And thanks to this must-read review by Kottner et al, clinicians now have a detailed explanation as to how changes in microclimate lead to deep tissue injury.

Although there are many pathways that may play a role, it seems to all come down to temperature and moisture. Higher temperatures at the surface are transferred to deeper tissues, resulting in greater susceptibility to injury. Too much or too little moisture increases the coefficient of friction, with resulting increases in shear deformation of subcutaneous tissues. What happens at the skin's surface really does matter.

ARTICLE 2

Alderden J, Pepper GA, Wilson A, et al. Predicting pressure injury in critical care patients: a machine learning approach. Am J Crit Care 2018;27:461-8.

The aim of this study was to develop a predictive model for pressure injury development among surgical critical care patients using data from the electronic health record. Rather than relying on standard statistical techniques, machine learning was used in model development to better address missing data and because it is relatively unaffected by moderate correlations among potential predictor variables. It also does not require clinicians to input information; rather, it uses the data already in the medical record. Despite these advantages, only limited evidence exists for the use of machine learning in predicting pressure injury development.

The study sample consisted of 6,376 patients admitted to the surgical or cardiovascular ICU of a single hospital between 2008 and 2013. Patients with a pressure injury that was present on admission or developed within 24 hours of admission were excluded from the sample. The mean age of the sample was 54 years; 62% of the sample were men, and 76% were white. The mean length of stay was 10 days. Pressure injuries of stage 2 or higher developed in 4% of the sample, and 8.1% developed any pressure injury. The most important predictors in both models for any pressure injury or for stage 2 or higher pressure injuries were body mass index, albumin, creatinine, glucose, hemoglobin, lactate, age, and surgical time. The area under the receiver operating characteristic (ROC) curve for both models was 0.79.

Limitations of the study identified by the authors were the absence of data on nursing interventions such as repositioning and use of data from a single hospital. The authors conclude that this machine learning approach is an effective method for using the electronic health record to identify predictors of pressure injury in the surgical ICU.

Comment

Pressure injury prevention is based on the premise that high-risk patients can be identified, specific interventions can be implemented directed at those risk factors that place someone at higher risk, and the interventions will be successful at mitigating the risk. However, there have been few advances in the tools available to identify at-risk individuals. Many clinicians continue to rely on prediction tools such as the Norton and Braden scales. Although these tools do have predictive validity, they were developed based on clinical judgments rather than empiric factors. Predictors in these scales may be highly correlated, and weights may be suboptimal.[5] Moreover, the ability of these scales to separate out high- and low-risk patients in ICUs is particularly poor because most patients have severe mobility and activity limitations. This is not necessarily surprising given that the Braden scale was originally developed for use in other healthcare settings. Known risk factors for pressure injuries in critical care patients also are not well captured by the Braden scale.[6] Studies evaluating the Braden scale in ICUs have demonstrated poor discrimination with an area under the ROC curve of 0.67.[7]

Machine learning with big data has the potential to create improved empirical models by evaluating a large number of predictors and combining them in ways that enhance prediction.[8] Preliminary applications to pressure injury prediction have been previously described,[9] and now Alderden et al demonstrate the importance of other clinical variables. Not only do physiologic measures such as body mass index, hemoglobin, creatinine, and glucose outperform the Braden scale in ICUs, but another study[10] also demonstrated that adding the Braden scale to a model based on clinical variables from the electronic medical record did not result in better model performance. Although the model developed by Alderden et al performed well, with an area under the ROC curve of 0.79, further validation in other samples of ICU patients is still required. Further, not all of the predictors identified by these authors are easily addressable in clinical practice; the causal pathway by which these factors result in pressure injury may be unclear.

Limitations of machine learning should also be recognized. Models are only as good as the data from which they are derived, and the use of machine-learning-derived models in other healthcare settings has rarely resulted in better patient outcomes when compared with standard approaches. That said, it is not hard to imagine that, in the future, identification of high-risk patients in the ICU will be guided by empirically derived models and not the Braden scale.

ARTICLE 3

Nixon J, Smith IL, Brown S, et al. Pressure relieving support surfaces for pressure ulcer prevention (PRESSURE 2): clinical and economic results of a randomised clinical trial. EClinicalMedicine 2019;14:42-52.

Literature supporting the use of specialized mattresses for pressure injury prevention is limited. In this pragmatic randomized clinical trial, the authors evaluated the clinical and cost effectiveness of an alternating pressure mattress (APM) versus a high-specification foam mattress (HSFM). The primary outcome was the time to development of a stage 2 or higher pressure injury from randomization to 30 days after the treatment on the mattress ended, up to a maximum of 90 days. There were several secondary outcomes, including time to development of a stage 3 or greater pressure injury and time to pressure injury development only while receiving the mattress treatment without the 30 days' posttreatment.

The sample consisted of 2,029 patients from 42 UK inpatient settings hospitalized between 2013 and 2016. Patients were all at high risk, with acute illness, moderate to severe functional dependence, or an existing pressure injury. The median age of the sample was 81 years (range, 21-105 years), 55% were female, and 98% were white.

Overall, a new stage 2 or higher pressure injury developed in 6.9% of the people receiving the APM and 8.9% of those using an HSFM. No significant difference was evident in the primary outcome (hazard ratio, 0.76; 95% confidence interval, 0.56-1.04). Only 1.6% of the sample developed a stage 3 or higher pressure injury, and there was no difference by support surface type. Restricting the analysis to pressure injuries that developed only while using the mattress revealed a significant benefit for the APM (hazard ratio, 0.66; 95% confidence interval, 0.46-0.93). The total costs of the APM were slightly less than the HSFM, and the use of the APM had a 99% probability of being cost effective at the threshold of 20,000 pounds per quality-adjusted life-year gained.

The authors highlighted several limitations, including the inability to blind the allocation of mattress type and that the study was underpowered because of difficulties in recruiting the sample, as well as a lower than expected pressure injury rate. The authors concluded there was insufficient evidence of a difference in time to pressure injury development. However, APMs should be considered in situations where HSF mattresses have failed.

Comment

Clinicians managing the prevention and treatment of pressure injuries are constantly being challenged by the absence of data from large, well-designed clinical trials. Nixon and colleagues are to be commended for these new data adding to their already impressive portfolio of clinical trials, including the PRESSURE 1 study comparing APMs and overlays, which provide impactful data for pressure injury prevention.[11] There is strong evidence that HSFMs are beneficial when compared with a standard hospital mattress for preventing pressure injury and should be considered a minimum intervention for high-risk individuals.[12] This new clinical trial evaluated whether a "high-tech" APM is superior to the "low-tech" HSFM—and the answer is a convincing maybe. There was no significant difference in the primary outcome, and even with 2,029 participants, the study was underpowered. However, a secondary analysis that considered only pressure injuries that developed during use of the beds did find a significant benefit to the APM. Any benefit, though, must be balanced with patient preferences; many people do not like the noise and discomfort associated with alternating pressure.

Several additional comments regarding the trial should be emphasized. First, this was a real-world study, and the mattresses used were not the same at different sites. A supplementary appendix to the article provides definitions for what constitutes one of these mattresses. Readers should not assume that all HSFMs and APMs are equivalent for prevention. Second, the fact that the study was underpowered was in part because of the lower than expected rate of pressure injury development. This is good in so far as it reflects ongoing success in improving pressure injury prevention. Finally, reading this study drives home the point that performing high-quality pressure injury prevention trials in a population of frail older adult patients with multiple comorbidities and cognitive impairment is really difficult. There is a reason so few data on pressure injury prevention are available from high-quality randomized clinical trials.

The authors finally conclude that this study provides the evidence underpinning current guideline recommendations for using HSFM in at-risk individuals and considering APM where the foam mattresses are failing. This is consistent with other published algorithms on the use of support surfaces.[13]

ARTICLE 4

Kwok AC, Simpson AM, Willcockson J, Donato DP, Goodwin IA, Agarwal JP. Complications and their associations following the surgical repair of pressure ulcers. Am J Surg 2018;216:1177-81.

Relatively few data exist on morbidity and mortality following the surgical repair of pressure injuries. Using a national, prospectively collected database of surgical cases, patients undergoing a pressure injury repair procedure were identified. Patients were followed up for the occurrence of a wide range of complications including surgical site infection, wound dehiscence, need for transfusion, sepsis, and 30-day mortality. Predictors of these complications were identified using a logistic regression model.

The study sample consisted of 1,248 individuals with a mean age of 54.5 years; 65.6% were male. Overall, a complication occurred in 35.0% of the sample, which had a 30-day mortality of 3.3%. Common complications included postoperative blood transfusion in 10.3% of those studied, surgical site infection in 8.1%, wound dehiscence in 4.6%, sepsis in 6.4%, urinary tract infection in 6.4%, and pneumonia in 2.2%. Only obesity was independently ($P < .05$) associated with an increased risk of complications. Having a flap closure was associated with fewer complications than other procedures. Predictors of postsurgical mortality ($P < .05$) were older age, history of diabetes, and functional dependency.

The authors conclude that the risk of complications is high following pressure injury repair, and careful patient selection is required to help mitigate these risks.

Comment

Stage 3 and 4 pressure injuries may require months or years to heal with conservative therapy, and surgical repair can provide rapid wound closure. However, indications for the surgical repair of pressure injuries remain poorly defined. As emphasized in the newly updated International Guideline[14] on pressure injuries, surgery requires careful consideration and discussion of a number of factors including the likelihood of healing with conservative therapy, the individual's goals of care, the individual's clinical condition including risk of surgery, and the individual's motivation and ability to adhere to the treatment regimen. Complicating discussions with patients and caregivers are very limited data on outcomes; much of the literature consists of small case series.

This article by Kwok et al provides important new data based on more than 1,200 cases in the American College of Surgeons National Surgical Quality Improvement Program database.[15] The 30-day complication rate from surgery was greater than 35% and included 3.3% mortality. This highlights how severe pressure injuries that may warrant surgery mostly occur in frail patients at high risk of future complications. Moreover, based on the relatively few factors identified as predictors of complications in the database, it is hard to do any risk stratification to identify those patients at highest risk.

These short-term outcomes must be combined with data on long-term pressure injury recurrence for complete decision-making. In one study,[16] the recurrence rate following 227 operations was 39%, and patients with multiple risk factors had near-zero operative success. Although such high complication and recurrence rates might suggest that surgical repair should be rarely considered, remember that successful surgery, especially when combined with a structured care program, is associated with improvements in health status.[17] The decision regarding the surgical repair of pressure injuries will rarely be easy, and given the many complications that may result, it must involve the patient, caregivers, and all clinicians.

ARTICLE 5

Padula WV, Pronovost PJ, Makic MBF, et al. Value of hospital resources for effective pressure injury prevention: a cost-effectiveness analysis. BMJ Qual Saf 2019;28:132-41.

This study analyzed the cost-effectiveness of three different strategies for preventing pressure injuries in hospital patients: (1) a strategy of prevention guidelines applied to all patients, (2) a strategy of prevention guidelines targeted only to high-risk patients based on low Braden scores, or (3) a strategy of current, standard care in which compliance with prevention guidelines is variable. For each of these cases, a Markov model was constructed, which considers different outcome states including development of a deep pressure injury (stage 3, stage 4, or unstageable), death, or discharge from the hospital. Transition probabilities among different states of the Markov model were generated from electronic health records of 34,787 patients using a machine learning approach.

Targeting prevention guidelines to patients with Braden scores of less than 15, 13, or 10 were all found to be dominant when compared with standard care. This means that it both saved money and yielded higher quality-adjusted life-years (QALYs). The prevention-for-all strategy resulted in the greatest increase in QALYs but was no longer cost saving, although the incremental cost to society was only $2,000 per QALY—well below the commonly established threshold of $100,000 per QALY for an intervention to be considered cost-effective.

The authors conclude that it makes sense for hospitals to invest in prevention infrastructure. Moreover, as the costs of treating a deep pressure injury escalate with new and more expensive interventions, the cost savings of preventing the pressure injury also will increase.

Comment

Successfully implementing and sustaining a pressure injury prevention program are difficult and require a team effort. Many barriers are likely to be encountered that can only be overcome with the strong support of hospital leadership.[18] That said, hospital leadership will have many competing priorities, and the implementation team will need to determine how best to engage leadership to ensure that adequate resources are available. In this day and age, the one thing that is sure to garner leadership's attention is a strong economic argument. This article by Padula et al provides the necessary information.

Prior work by this team has demonstrated that pressure injury prevention directed at hospital patients saves money over the course of a year.[19] This study provided further information about different prevention strategies that could be implemented. The good news is that targeting pressure injury prevention to patients with low Braden scores, when compared with standard care, does save money and results in better health as measured by QALYs. Further, a small investment to provide pressure injury prevention to all patients results in the greatest increase in QALYs. The $2,000 per QALY gained is in the range that is generally considered highly cost-effective. Every clinician interested in wound care should be striving to reduce pressure injury rates in his/her hospital and can use these data to convince his/her leadership to provide the necessary resources to ensure the success of a prevention program.

ARTICLE 6

Smith S, Snyder A, McMahon LF, Petersen L, Meddings J. Success in hospital-acquired pressure ulcer prevention: a tale in two data sets. Health Aff (Millwood) 2018;37(11):1787-96.

Medicare measures hospital pressure injury rates as a part of three different programs: the Hospital-Acquired Conditions Initiative, Hospital-Acquired Condition Reduction Program, and Hospital Value-Based Purchasing Program. These programs aim to incentivize hospitals to provide higher quality care. Although all three programs use administrative data in calculating pressure injury rates, they differ in which patients are included in the denominator, whether to count all pressure injuries or only those of higher stage, and whether to exclude pressure injuries present on admission. The article by Smith et al used the Medicare definitions to calculate trends in pressure injuries from 2009 to 2014 in three large states and compared those findings to surveillance rates from medical charts produced by the Agency for Healthcare Research and Quality (AHRQ), which revealed a 23% decline in hospital-acquired pressure injuries from 4.02% to 3.09%.

Using the Hospital-Acquired Conditions Initiative definition, the hospital-acquired pressure injury rate declined from 2009 to 2014 by 40%, from 0.27% to 0.16%. (Most of this change was in stage 1 and 2 pressure injuries, with only minimal change in higher stage injuries.) With the definition used in the other two Medicare programs, which considers only higher-stage pressure injuries, a nonsignificant 7.6% decline was noted, from 0.043% in 2009 to 0.040% in 2014.

These results confirm findings from other studies based on administrative data that show pressure injury incidence is approximately one-twentieth that of other data sources. Much of the improvement in pressure injury rates is attributable to the prevention of early-stage wounds, minimizing any presumed impact from the Medicare programs on health and costs. The authors recommend that Medicare develop a pressure injury surveillance system that does not rely on administrative data alone.

Comment

Measurements of pressure injury rates have become ubiquitous. Prevalence rates are available on the CMS Nursing Home Compare website, and composites that include pressure injuries as part of an overall complication rate are available on Hospital Compare. They are used for adjusting hospital reimbursements. This article describes trends in pressure injury based on *International Classification of Diseases* codes in administrative databases used for hospital reimbursements in Medicare value-based purchasing programs.

The good news is that, based on these data, there was a large decrease in hospital-acquired pressure injury rates between 2009 and 2014. However, this must be tempered with several concerns. First, the overall pressure injury rate based on administrative data was one-twentieth of that found in chart-based data. This mirrors other studies[20,21] demonstrating the problems with using *International Classification of Diseases* codes and the present-on-admission designation in calculating pressure injury rates. Second, most of the decline is attributable to prevention of stage 1 and 2 pressure injuries and not the stage 3 and 4 wounds that clinicians are most concerned about. Third, 2015 to 2017 data from the AHRQ suggest that pressure injury rates may be increasing.[22] Of course, this latest AHRQ report uses the same administrative data as in the article by Smith et al, raising concerns as to overall completeness and accuracy.

Clinicians and government agencies need good data when addressing important topics such as hospital reimbursement and quality of care. It seems unlikely that such good data will come from the continued mining of administrative databases in calculating pressure injury rates.

CONCLUSIONS

Pressure injury research continues to expand. The articles highlighted in this review are making important new contributions to the field that will shape the prevention and treatment of pressure injuries. Highlighted articles guide risk stratification, prevention strategies, the use of support surfaces, and the role of pressure injury surgery. Of particular note are the sample sizes for the selected research studies. Many of them are based on samples of thousands of patients, which helps ensure validity. As with all research, clinicians must determine how to use these results to impact their practice. Hopefully, research in coming years will continue to offer high-quality and impactful contributions to the literature.

PRACTICE PEARLS

- Attention to the skin microclimate can help prevent the development of pressure injuries.
- Physiologic measures may be useful in predicting pressure injury development in ICU patients.
- Complications following pressure injury surgery occur in more than one-third of patients.
- The benefits of an alternating pressure mattress compared with a high-specification foam mattress in preventing pressure injury are uncertain.
- Pressure injury prevention is cost-effective. ●

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