Chapter 3
Prevention of Pressure Ulcers

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Abstract Pressure ulcers (PU) cause significant morbidity in the frail elderly and neurologically impaired individuals. The cost of care may exceed $70,000 and treatment in the USA is estimated at $1.1 billion annually. New products and support surfaces are continually entering the marketplace. There has been heightened awareness of the problem and many evidence-based guidelines have been disseminated over the last decade. In spite of this there has been not been a dramatic decline in PU incidence worldwide.

Experts agree that not all PUs are avoidable. There are occasions when an ulcer develops in the face of good care. This chapter outlines the best practices for risk assessment and prevention. The tools and practices discussed can be applied to all care settings with the goal to reduce the incidence and, thereby, the prevalence of PUs.

Keywords Pressure ulcer • Prevention • Staging • Aging • Support surface • Skin assesment • Braden scale

Introduction

Pressure Ulcers (PU) are defined as "localized injury to the skin and/or underlying tissue usually over a bony prominence as a result of pressure, or pressure in combination with shear and/or friction" [1]. Pressure ulcers occur when soft tissue is compressed between a bony prominence and an external surface for a prolonged

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time [1]. Compression causes diminished blood supply, which in turn leads to decreased oxygen and nutrient delivery to the affected tissues. These decreases cause the affected tissue to become ischemic and potentially necrotic [2].

Reports of PU incidence vary widely, from 0.4 to 38 % in acute care, from 2.2 to 23.9 % in long-term care, and from 0 to 17 % in home care, according to a report from the NPUAP [3]. Prevalence rates show the same variability: 10–18 % in acute care, 2.3–28 % in long-term care, and 0–29 % in home care [3]. The National Pressure Ulcer Advisory Panel has provided a mechanism for grading the stage of a pressure ulcer. The system has six stages: suspected deep-tissue injury, Stage I, Stage II, Stage III, Stage IV, and stageable. Because pressure ulcers are costly, take a substantial time to heal, and are a significant cause of morbidity and mortality, it is important to discuss prevention of pressure ulcers.

The Centers for Medicare and Medicaid ruling on the Inpatient Prospective Payment System states that hospitals are no longer reimbursed for care related to Stage III and Stage IV pressure ulcers that develop during a hospital admission [4].

Skin Assessment

On admission to an acute care, long-term care, or on first contact in the outpatient setting, an admission assessment should be completed that includes both a skin assessment to identify and describe any breakdown present on admission and a risk assessment to identify any patient at risk for breakdown. The skin assessment is a key component to prevention of pressure ulcers. The medical provider (MD, NP, PA) may delegate the skin assessment to other staff; however if there is inappropriate supervision, they may be at risk of litigation [5]. National Institute for Health and Clinical Excellence Pressure ulcer Guidelines [6] suggests that patients should be assessed in the hospital or emergency room within 6 h of their first episode of care, and on first contact in the outpatient setting. Assessment findings should be documented and reviewed at least weekly. A reassessment should be carried out whenever there is a change in the patient's physical and/or mental state, whether it is improving or deteriorating [6]. For Stage I pressure ulcers, the definition requires non-blanchable erythema [7]. The absence of blanching implies that the blood supply is not intact [7]. There has been a suspicion that Stage I presure ulcers are unrecognized and underreported in patients with darker skin. In these patients, the area of discolouration may be observed as being slightly darker than the surrounding skin. The blanch test will not show the pallor usually seen in lighter skin because of the presence of melanin. Therefore, other key indicators should be used alongside this test in patients with darker skin [8]. An increase or decrease in skin temperature can be indicative of pressure damage. An increase in temperature at the area can indicate inflammation or infection with cool skin indicating poor perfusion and ischemia [7]. Skin areas should be palpated for edema, which occurs in the tissues as the skin layers become separated and interstitial fluid accumulates between them [7]. Depending on staff expertise, classification/staging may be done by staff or staff

describing the wound and utilizing a specific wound team or physician to classify and stage a wound. A certain level of expertise may be required to differentiate between a pressure ulcer and moisture-associated skin damage.

Pressure Ulcer Risk Assessment Scales

Pancorbo-Hildago et al. conducted a systematic review of 33 studies regarding PU risk assessment scales currently available for use. They found that the use of these scales has not changed the incidence of PUs, but they are still better risk predictors than nurses' clinical judgment [9]. Pressure ulcer risk assessment tools currently used worldwide are the Norton Scale, published in England in 1962, the Waterlow Scale, published in England in 1984, and the Braden tool, published in the USA in 1987 [10]. The most widely used and tested of all risk assessment tools is the Braden Scale for Predicting Pressure Sore Risk developed by Barbara Braden and Nancy Bergstrom [11]. The Braden Scale is an instrument that has undergone repeated testing (with varying reports of inter-rater reliability) and consists of six subscales/subscores used by healthcare providers to assess risk factors that are associated with PU development [12]. The Braden tool, like its predecessors, was developed and initially tested for validity among elderly populations in nursing home settings [11].

Braden Scale

The Braden scale is an overall numeric rating comprised of six subscales: sensory perception, mobility, activity, moisture, nutrition, and friction and shear. The six subscales are rated from 1 to 4 except the friction and shear subscale, which is rated from 1 to 3. Each numerical rating has a definition of patient characteristics to evaluate when assigning a score. A total of 6–23 points is possible, with lower numbers representing increased risk. The original critical cutoff point for defining high risk is 16 [11]. Other investigators have suggested setting 18 as the cutoff score to increase specificity and reduce the risk of false-positive screens for older patients and African-American and Latino patients [13, 14]. Certain Braden subscale definitions (such as patient's dietary intake or frequency of skin being moist) are more difficult for nurses to objectively measure or appropriately quantify than other Braden subscale factors such as activity level [10].

Gosnell Scale

The Gosnell Scale consists of five parameters—mental status, continence, mobility, activity, and nutrition with varying points (1–3 for nutrition; 1–4 for continence, mobility, and activity, and 1–5 for mental status). The scoring for each parameter is

clarified by brief descriptive statements. The Gosnell Scale documents additional variables, including body vital signs, skin appearance, diet, 24-h fluid balance, medication, and interventions; however, these variables are not given weight in the final score. Possible Scores for the Gosnell Scale range from 5 to 20, with higher scores representing increased risk [15].

Norton Scale

The first pressure ulcer risk assessment scale was the Norton scale. It consists of five parameters: physical condition, mental state, activity, mobility, and incontinence. Each parameter is rated on a scale from 1 to 4, with a 1-, 2-, 3-word descriptor for each rating. The sum of the ratings for all five parameters yields a score ranging from 5 to 20, with lower scores indicating an increased risk. A score of 14 or lower indicates a risk for pressure ulcer formation [16].

Waterlow Scale

The Waterlow scale is based on the Norton Scale but is considered to be more comprehensive. The Waterlow Scale consists of eight items: build/weight for height, visual assessment of the skin in the area at risk, sex and age, continence, mobility, appetite, medication, and special risk factors. The highest and lowest scores of each item vary. The scores of mobility range from 0 to 5; scores for appetite range from 0 to 3. Patients scoring 10–14 are identified as being at risk for pressure ulcer formation. A score of 16 or below is the usual cutoff point for at-risk patients in clinical studies again with lower scores indicating a higher risk for pressure ulcer development [17].

Ramstadius Tool

The Ramstadius tool is the only assessment tool with just two questions. One question relates to skin integrity and the other to mobility. If both questions are answered "yes" the patient is considered at high risk for pressure ulcer development. However, the Ramstadius tool is not widely used and requires validation for its use as a predictive tool in a nursing home population [18].

Special Populations

SCI Patients

Salzberg et al. mailed a questionnaire to almost 2,300 members of the Eastern Paralyzed Veterans Association that sought to measure 45 potential risk factors for pressure ulcers. The survey had a 42 % response rate. There were seven risk factors that were independent predictors of pressure ulcer development: level of activity, level of mobility, complete spinal cord injury, urine incontinence or moisture, autonomic dysreflexia, pulmonary disease, and renal disease. In addition two other variables added to the predictive value, being prone to infection that causes breathing problems and paralysis caused by trauma as opposed to disease. Using these nine risk factors, the authors developed a new pressure ulcer risk assessment scale specifically for persons with paralysis who are living in a community setting. It appears to be more accurate than other scales in this population [19].

Pressure ulcer risk assessment scales, including the Braden Scale, tend to over-predict risk; as noted, this may be due to an inherent weakness in the tool itself or may reflect the effectiveness of currently used prevention protocols. Bolton in 2007 reviewed the MEDLINE electronic data base from January 1966 through March 2007 for the key term "pressure ulcer risk assessment" combined with the search terms (1) controlled study, (2) validity, (3) positive predictive value, (4) sensitivity, (5) negative predictive value, and (6) specificity. The majority of ICU patients in this review were found to be at risk for PU development based on the Braden Scale Score but did not develop a PU; it is unknown whether this represents true over-prediction or is the result of preventive care. In the first scenario, over-prediction may be the result of an intrinsic weakness of the scale and results in the unnecessary implementation of prevention protocols, which could impact healthcare costs. In this case, the refinement or development of a scale that better measures PU risk in the population would be warranted. In the second scenario, the apparent over-prediction may reflect the successful implementation of PU-prevention protocols; identification of the patient as being "at risk" triggered preventive care that actually prevented PU occurrence. Clinically, the second scenario validates the benefits of a comprehensive PU-prevention program. Since withholding PU-prevention strategies would be unethical, it is impossible to conduct a study to definitively determine whether the apparent over-prediction is true over-prediction or the result of effective care. In clinical practice, the consequences of under-prediction would far outweigh the costs of over-prediction (see Table 3.1).

Care Settings: Because pressure ulcer prevention differs so significantly by setting and by the patients seen in such settings, we have broken down further discussion of prevention by setting of care.

Table 3.1 Key points from Bolton review (2007) on pressure ulcer assessment tools [20]

1. The Braden and then Norton and Waterlow PU risk assessment scales have been found valid for the prediction of PU risk in a variety of healthcare settings and in multiple countries (level of evidence 1)
2. The Braden and Norton Scales have demonstrated inter-rater reliability when administered by RN's and LPNs (level of evidence 2)
3. A validated PURAS (Pressure ulcer risk assessment scale) should be administered by a professional nurse. Limited evidence suggests that the predictive validity of the Norton scale may be increased if it is administered by a nurse who has provided direct care of the patient undergoing risk assessment (level of evidence 2)
4. A cut point that differentiates clinically significant risk for PU development should be used for each scale. This value may vary based on setting (level of evidence 2)
5. A PURAS should be administered to all patients with 1 or more risk factors for pressure ulceration when admitted to a hospital's surgical, intensive care, orthopedic, cardiovascular, medical or step-down units, home care, hospice, or an extended care facility (level of evidence 2)
6. Administration of a PURAS is not indicated for patients without risk factors who undergo a brief period of immobility owing to surgery (level of evidence 2)
7. Pressure ulcer risk assessment should be performed on home care patients upon admission, and then weekly or biweekly until discharge (level of evidence 2) [20]

Acute Care

The acute care setting is an important site for pressure ulcer prevention because patients are acutely ill, often have limited mobility with resultant difficulty in relieving pressure, and may be nutritionally compromised. Fogerty conducted a large case–control study that reviewed admission and discharge data from over six million subjects (Nationwide Inpatient Sample) within acute hospital settings to identify risk factors and demographic differences between those who developed PU Pus and those who did not. Using multivariate logistic regression (LR) analysis examining the 45 most common diagnoses identified in persons with pressure ulcers, they reported the odds ratios (ORs) for the most significant risk factors associated with developing pressure ulcers. Analysis was also conducted stratifying the sample by age, race, and gender. Age over 75 years was the strongest PU risk factor identified with an OR of 12.63. Other strong risk factors identified by Fogerty included more than 28 medical diagnoses with an OR > 2. Age 59–75 years was a strong risk factor (OR 5.99), as was African-American race (OR 5.71). Other significant findings identified in the study highlight some of the strongest risk factors that are non-modifiable (age, paralysis, and race) while others are potentially modifiable (infection and nutritional deficiencies). A majority of the strongest risk factors identified are not accounted for in the Braden tool [21].

Cowan sought to determine if a PU predictive model could be identified specific to acute care to enhance the Braden scale which is currently utilized within facilities caring for US veterans. They investigated diagnosis of gangrene, anemia, diabetes, malnutrition, osteomyelitis, pneumonia/pneumonitis, septicemia, candidaisis, bacterial skin infection, device/implant/graft complications, urinary tract infection,

Table 3.2 Comparison of pressure ulcer risk assessment scales

Predictive power	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Norton	49	100	100	52	66
Braden	53	100	100	58	71
Gosnell	85	83	59	95	83
Waterlow	63	82.5	61	84	77

Table created from data in [23]
PPV postive predictive value, *NPV* negative predictive value

paralysis, senility, respiratory failure, acute renal failure, cerebrovascular accident, or CHF during hospitalization, patient's age, race, smoking status, history of previous PU, surgery, hours in surgery, length of hospitalization, and ICU days. Retrospective chart review and logistic regression analysis were used to examine Braden scores and other risk factors in 100 acutely ill veterans with PUs and 113 without PUs. Cowan found that malnutrition, pneumonia/pneumonitis, candidiasis, and surgery have stronger predictive value (sensitivity 83 %, specificity 72 %, area under receiver opering characteristic curve (ROC) 0.82) for predicting pressure ulcers in acutely ill veterans. The Braden scale total scores alone had sensitivity of 65 %, specificity 70 %, and an area under the ROC curve 0.70 (with 0.5 equivalent to chance, and 1.0 as perfect discrimination). Combining the four medical factors and two Braden subscores (activity and friction) demonstrated better overall model performance (sensitivity 80 %, specificity 76 %, and area under the ROC curve of 0.88) [22].

Jalali conducted a prospective clinical design study in which 230 subjects free of pressure ulceration on admission were assessed using the Braden, Gosnell, Norton, and Waterlow scales within 48 h of admission. Subjects' skin condition was assessed once every 24 h for a minimum of 14 days to identify any skin breakdown. As this study was conducted in Iran, the results may not be widely applicable to acute care settings elsewhere [23] (see Table 3.2).

Webster performed a single blind randomized control trial in Australia to assess the effectiveness of two-pressure ulcer screening tools against clinical judgement in preventing pressure ulcers. 1,231 patients were allocated to either a Waterlow or Ramstadius screening tool or to a clinical judgment group. There were 5.8 % of the patients who had an existing pressure ulcer on admission. Incidence of hospital-acquired pressure ulcers was similar between groups, clinical judgment (6.8 %), Waterlow (7.5 %), or Ramstadius (5.4 %) $P=0.44$. Significant associations with pressure injury in regression included requiring a dietetic referral, being admitted from a location other than home, and age over 65 years [24].

Surgical: Acute Care

Pressure ulcers can develop in a short time (as quickly as 3 days for postoperative patients) [25]. Patients undergoing surgical prodedures who are immobile for long periods and are unable to change positions are at greater risk than patients

who are mobile. Because of sedation, anesthesia, and paralysis, surgical patients cannot meaningfully sense the numbness or pain that prolonged pressure causes and subsequently are unable to change position to relieve the pressure. The incidence of pressure ulcers among surgical patients can be as high as 45 % and the risk increases among older adults [26]. Bales performed a quasi-experimental clinical trial to test the efficacy of using intravenous bags as compared to a commercially available heel suspension foam boot. The target population was individuals admitted to the hospital for a hip or knee replacement between the ages of 55 and 70 years old. No patients using a foam boot (0/15) showed signs or symptoms of pressure, but 6/15 using an IV bag to "float" the heel had blanchable erythema and warmth present upon assessment [27].

Tschannen examined the relationship between patient characteristics (age, sex, BMI, history of diabetes, and [28] Braden Scale Score at admission) and care characteristics (total operating room time, multiple surgeries, and vasopressor use) and the development of pressure ulcers. The cohort study reviewed data from 3,225 surgical patients from November 2008 to August 2009. 12 % of the patients ($N=383$) had at least 1 pressure ulcer devlop during their hospitalization. According to logistic regression analysis, scores on the Braden Scale at admission ($P<0.001$), low body mass index ($P<0.001$), number of vasopressors ($P=0.03$), multiple surgeries during the admission ($P<0.001$), total surgery time ($P<0.001$), and risk for mortality ($P<0.001$) were significant predictors of pressure ulcers [29]. Schoonhoven found that total operating room time was significantly associated with the occurrence of pressure ulcers. For every 30 min the surgery went beyond 4 h, and the risk for a pressure ulcer increased by approximately 33 %. Further surgeries may result in more episodes of increased pressure on the capillaries when a patient is immobile because of sedation. This increase may in part be rleated to the amount of time a patient is completely immobile and unable to relieve pressure on bony prominences [30]. Pressure ulcers that are first noticed in postoperative units such as the Surgical Intensive Care Unit may be a result of unrelieved pressure in the operating room. Patient's recovery from the surgical operation would be lengthed with increased cost and morbidity due to an acquired pressure ulcer.

Long-Term Care

The long-term care setting is an appropriate site for discussion of prevention because the nursing home population is at increased risk for pressure ulcer development. The long-term care patient may have physical limitations that result in dependance on staff for bed mobility and pressure relief, cognitive limitations that make compliance with positioning difficult, malnutrition for various reasons, and a problem list of medical diagnosis such as vascular disease and diabetes that predispose them to the development of pressure ulcers. Ba'Pham used a validated Markov model to compare current prevention practices with four quality improvement strategies (1) pressure redistribution mattresses for all residents (bed); (2) oral nutritional

supplements for high-risk residents with recent weight loss (vitamin); (3) skin emollients for high-risk residents with dry skin (lotion); and (4) foam cleansing for high-risk residents requiring incontinence care (continence). Primary outcomes included lifetime risk of stages II–IV pressure ulcers, QALYs, and lifetime costs. The NNT for each strategy was 45 (bed), 33 (vitamin), 158 (lotion), and 63 (continence), respectively, by number. Strategy 1 (bed) and 4 (continence) minimally improved QALYs and reduced the mean lifetime cost by $115 and $179 per resident. The cost per QALY gained was $78,000 for strategy 3 (lotion) and $7.8 million for strategy 2 (vitamin). If decision makers are willing to pay $50,000 for 1 QALY gained, the probability that improving prevention is cost-effective is 94 % (continence), 82 % (bed), 43 %(lotion), and 1 %(vitamin) [31].

Home Care

Home Care is an understudied area for pressure ulcer prevention and it is important to discuss because development of pressure ulcers in the home can result in costs associated with home health nursing for treatment, an increase in hospitalizations due to complications from pressure ulcers, and increased risk of nursing home placment for treatment and further prevention. Although numerous studies have examined risk factors for pressure ulcer development among hospitalized and long-term care patients, only one study and its secondary analysis have examined risk factors for pressure ulcer development in home health care. Risk factors for pressure ulcers differed from those found in long-term care studies, including oxygen use, having an adult child as the primary caregiver, and skin damage. The complete model with risk factors for higher PU development, using Cox regression analysis using time until incident ulceration, included male sex, needing assistance with dressing, being wheelchair bound, bowel/bladder incontinence, anemia, and recent fracture [32, 33].

Home healthcare agencies must collect OASIS data, which are nationally standardized and have established validity and reliability for payment of services provided to Medicare and Medicaid patients in the USA [34]. Researchers have attempted to utilize the OASIS data as a predictive model for the development of pressure ulcers. Bergquist-Beringer measured OASIS data on 3,323 females (61.6 %) and 2,072 males (38.4 %) ranging in age from 60 to 103 years. The cumulative incidence of pressure ulcers for the population was 1.3 % ($N=71$). Multiple logistic regression analyses revealed that bowel incontinence, needing assistance with grooming, dependence in ability to dress the lower body, dependence in toileting, inability to transfer, being chairfast or bedfast, and the presence of a pressure ulcer on admission were positively associated seating surfaces to patients only if they have a wheelchair. CMS also added process measures to their data collection in Outcome and Assessment Information Set (OASIS)-C. There are three that relate to pressure ulcers (1) whether or not a pressure ulcer risk assessment was conducted, (2) whether or not a pressure ulcer prevention plan was present in the plan of care, and (3) whether

or not a pressure ulcer prevention intervention was evident in the short-term episode of care. This indicates the degree to which CMS is serious about pursuing a decline in the number of pressure ulcers occurring across all settings. These indicators are reported to the federal government and published on the CMS Web Site comparing a home care agency's outcomes in these areas to national and regional benchmarks since 2000 [35].

Hill-Brown in 2011 carried out a quality improvement project to provide pressure reduction cushions for veterans at high risk for pressure ulcers that did not have a wheelchair cushion. Pressure ulcers were reduced in this population of approximately 1,200 patients from around 23 pressure ulcers per year to 2 pressure ulcers per year following cushion distribution [36].

Patient Specific Risk Factors

Advanced Age

Increasing age has been found to be significantly associated with pressure ulcer development. While an important risk factor, age is essentially non-modifiable. The skin of older patients is drier, fragile, and easily injured [37]. The epidermis thins and cell turnover slows, with cell loss occurring more rapidly than cell replacement. Protective function of the epidermis is compromised. Temperature control is lessened with the loss of sweat glands and collagen renewal deteriorates with age. Emollients are helpful for dry skin [38].

Nutrition

Nutrition has been shown to be important for pressure ulcer prevention, in that populations with poor nutritional status have higher rates of pressure ulcer incidence. The loss of body fat reserves reduces the natural padding over bones, increasing the vulnerability to pressure and soft tissue breakdown [38]. A large retrospective cohort study of 2,420 adult nursing home residents with a stay of 14 or more days and with a risk of developing a pressure ulcer documented that an unintentional weight loss at any body mass index increased the chance of developing a pressure ulcer by 147 % [39]. Maintenance of adequate hydration is important. Well-hydrated skin is healthier skin and thus less vulnerable to breakdown [40, 41].

There are several tools to assess nutritional status. Among these is the Subjective Global Assessment of Nutritional Status. This scale is used to identify patients at risk of nutrition-related complications using information from the patients' history and physical examination [42]. Although serum albumin levels have long been used clinically, they are a poor indicator of visceral protein status related to albumin's long half-life (12–21 days) and numerous factors that decrease albumin levels even

in the presence of adequate protein intake [38]. Measurement of actual oral intake through nutrient intake studies or monitoring body weight provides more reliable data from which to make clinical decisions. The NPUAP recommends to offer individuals with nutritional and pressure ulcer risks a minimum of 30–35 kcal per kg body weight per day with 1.25–1.5 g/kg/day protein and 1 ml of fluid intake per kcal per day [43]. While we currently lack specific studies that provide statistical evidence that nutritional and fluid support helps to reduce the risk of pressure ulcer development, most evidence-based guidelines include strong recommendations for nutritional assessment and support. For example, the NPUAP/EPUAP Guidelines include the following recommendations:

1. Identify and correct factors compromising protein per cal intake consistent with overall goals of care.
2. Consider nutritional supplementation/support for nutritionally compromised persons consistent with overall goals of care.
3. If appropriate offer a glass of water when turning to keep patient/resident hydrated.
4. Multivitamins with minerals per physician's order.

Immobility

All risk assessment tools include immobility as a risk factor and the two interventions currently recommended for addressing this risk factor are routine turning and positioning, and use of pressure reducing support surfaces [38]. The risk of pressure ulcer development is compounded when the patient is older and has concurrent illnesses that impair mobility or activity [37]. Standard mattresses are filled with springs and low-density foam. Pressure reduction support surfaces (PRSS) are filled with alternative materials such as gel, fiber, and air [44]. Several clinical guidelines recommend that all people at risk for pressure ulcers should use pressure reduction support surfaces. However, the evidence to support the effectiveness of PRSS is limited [45]. The National Pressure Ulcer Advisory Panel categorizes PRSS to powered support surfaces which include alternating pressure, low-air loss, and air-fluidized mattresses and alternating pressure overlays. Non-powered support surfaces include static air, gel-filled, fiber-filled, water-filled, and high-density foam mattresses and pressure redistributing overlays other than alternating pressure overlays. Powered PRSSs generally cost 100–1,000 of dollars to rent or purchase. Nonpowered PRSS generally cost less than $300. The difference in cost and style of mattress makes it important to determine if powered PRSS is more effective than non-powered [46]. Russell in 2003 performed an unblinded randomized prospective trial to determine whether a viscoelastic polymer foam mattress was superior to a standard hospital mattress for pressure ulcer prevention and to analyze the cost-effectiveness in comparison with standard hospital mattresses. A significant decrease in the incidence of blanching erythema and nonsignificant decrease in nonblanching erythema were found in patients allocated to the experimental group. To prevent

nonblanching erythema the number needed to treat was 41.9 and the NNT was 11.5 to prevent any erythema. Patients with blanching or nonblanching erythema were significantly less mobile than participants with normal skin and more likely to have worsening mobility ($P < 0.001$) [47]. Comfort in 2008 performed a literature review to examine hospitals that utilized the Braden scale to identify at-risk patients and providing pressure-reducing surfaces to those found to be at risk. He found that although the programs put in place by the hospitals were not precisely the same, they could expect to reduce the odds that a patient will develop a pressure ulcer somewhere between a factor of 2 and 5 [48]. Xakellis, working at a 77-bed long-term care facility, provided inexpensive 2- and 4-in. foam overlays to those patients determined to be at risk for pressure ulcers based on a Braden Scale assessment. They used a staged approach providing overlay alone, turning schedule alone, or both turning schedule and overlay depending on the level of risk identified. This approach was successful in reducing the 6-month incidence rate from 23 % pre-protocol (16 of 69) to 5 % post-protocol (3 of 63) [49]. Rich performed a secondary analysis from prospective cohort study to evaluate the association between pressure-redistributing support surface (PRSS) use and incident pressure ulcers in older adults with hip fracture. Full-body examination for pressure ulcers, bed-bound status, and PRSS userecorded as none, powered, or non-powered. Incident pressure ulcers stage II or higher were observed in 4.2 % of visits after no PRSS use, 4.5 % of visits after powered PRSS use, and 3.6 % of visits after non-powered PRSS use. This study found that in a high-risk population there is little or no preventive effect of PRSS use in nonbed-bound patients at risk of pressure ulcers [45].

A recent Cochrane Review found good evidence of the superiority of high-specification foam over standard hospital foam, yet it was not able to determine the most effective support surface for pressure ulcer prevention or treatment. The review identified 29 pressure ulcer prevention trials and concluded that the methodologic quality was generally poor and that randomization was only adequate in only 22 % of trials. Four trials demonstrated a statistically significant reduction in the incidence and severity of pressure ulcers in high-risk patients when compared with patients on a standard foam mattress [50]. Despite the lack of compelling data, most evidence-based guidelines for pressure ulcer prevention do include a recommendation that at-risk patients be placed on a PRSS. Physiologically this makes sense, in that more conformable surfaces reduce the interface pressure over bony prominences, which translates into improved tissue perfusion.

Currently there is limited evidence to suggest that repositioning every 4 h when combined with any pressure redistributing mattress is just as effective for prevention of pressure ulcers as more frequent (every 2 h) repositioning or turning. Evidence for the optimal frequency of repositioning is lacking. Turning every 4 h in combination with the use of a viscoelastic foam redistributing mattress was shown to decrease the occurrence of pressure ulcers compared to turning every 2 or 4 h on a non-pressure redistributing mattress. Repositioning frequency should be determined by individual, activity/mobility level, and overall medical condition. In some individuals, regular turning and repositioning may not be possible because of their medical condition so consideration should be given to upgrade the support surface

for these individuals. Frequent small position changes using pillows and wedges reduce pressure over bony prominences. Pad between skin surfaces such as knees that may rub together. Repositioning and use of pillows with continuous lateral rotation therapy need further research to determine its effectiveness on pressure ulcer prevention. Acute spinal cord injured patients may require more frequent turning than every 2 h due to microvascular dysfunction [51].

The NPUAP/EUPAP recommendations for pressure reduction support surfaces include:

1. Reposition bed-bound persons at least every 2 h and chair-bound persons every hour consistent with overall goals of care.
2. Use a written repositioning schedule.
3. Place at-risk persons on pressure-redistributing mattress and chair cushion surfaces.
4. Avoid using donut-type devices and sheepskin for pressure redistribution.
5. Use pressure-redistributing devices in the operating room for individuals assessed to be at high risk for pressure ulcer development.
6. Use pillows or foam wedges to keep bony prominences, such as knees and ankles, from direct contact with each other. Pad skin subjected to device-related pressure and inspect regularly.
7. Avoid positioning directly on the trochanter when using the side-lying position; use the 30° lateral inclined position.
8. Institute a rehabilitation program to maintain or improve mobility/activity status.

Friction and Shear

Friction can cause injury to the individuals skin from movement of the skin on the bed linens. Friction injuries can also develop in individuals who are in pain but are not able to process the meaning of the sensation of pain (those with confusion or dementia). Rubbing the heels on the bed is a commonly seen friction injury, which can quickly lead to superficial tissue damage on the heels. Shear stress is the "force per unit area exerted parallel to the plane of interest." Shear strain is the distortion or deformation of tissue as a result of shear stress. Friction is necessary for shear to occur and shear forces can damage the skin internally which is likely to occur when a resident must sit up in bed and then slides down [38, 52].

Exposure to Excess Moisture

Skin moisture from incontinence can be a risk factor for pressure ulcer development. The etiology of the incontinence should be identified and eliminated if possible. Moisture can arise from perspiration, wound exudates, urine, and/or feces. Sweat is not immediately toxic to skin but can result in epithelial injury through several

mechanisms. Sweat between skin folds creates a warm moist environment and promotes growth of several forms of bacteria and yeast [53]. Normal skin pH is acidic at 4–6.5, which helps protect the skin against microorganism invasion. Frequent use of soap can alter skin pH to an alkaline state, leaving it more vulnerable to microorganism invasion. Skin that is water logged from continual wetness is more easily subjected to breakdown, injured by friction, permeable to irritating substances, and able to be colonized by microorganisms than normal skin as well as pressure ulcer deterioration. Exposure to urine or diarrhea damages the skin and increases the risk of pressure ulcers. Urine is absorbed by keratinocytes, and when these cells are softened, they cannot provide protection from pressure injury. Urine contains urea, and ammonia can damage the skin. In an incontinent individual with a urinary tract infection, urine will also be alkaline and injurious to the skin [38]. Diarrhea strips the outer layer of skin, and the exposed dermis cannot tolerate pressure. Diarrheal fluids are caustic and can damage the skin quickly. When urine is present in combination with feces, which contains bacteria and harsh gastrointestinal enzymes, the damage can be even quicker and more severe. In addition to this chemical irritation, the mechanical irritation from cleaning the individual can compound the damage [38]. The Wound Ostomy and Continence Nurses Society in 2010 published guidelines that recommend cleansing skin gently at each time of soiling with pH-balanced cleansers. The use of perineal skin cleansers has been found to be more effective for the prevention and treatment of incontinence-associated dermatitis (IAD) than traditional soap and water. Bar soap tends to dry the skin and create an alkaline pH on the epidermal skin surface increasing the risk of tissue injury. Vigorous cleaning can also lead to erosion of the epidermis. Smoothly woven disposable cloths are preferred over washcloths, which can increase friction at the skin's surface. Products with known irritants such as fragrance and alcohol should be avoided. Another cleaning option is the use of no-rinse cleansing foam. The WOCN also recommends using incontinence skin barriers such as creams, ointments, pastes, and film-forming skin protectants as needed to protect and maintain intact skin while avoiding products with humectants (urea, glycerin, alpha hydroxyl acids, and lactic acid). These products retain water in the skin, but with IAD the skin is over hydrated and does not need the added moisture from these products. The use of a skin protectant (i.e., dimethicone, liquid clear film barrier, petroleum, or zinc oxide) is recommended for individuals with frequent fecal incontinence or double urinary and fecal incontinence to protect against IAD.

Prevention of Heel Ulcerations

Epidemiologic data suggest that the heel is the second most common site behind the sacrum for pressure ulcers [54]. Heel pressure ulcers can cost $2,000–$30,000 to treat [55]. Prevalence data from more than 85,000 patients reveal that heel pressure ulcers account for 23.7 % of ulcers seen in acute care facilities, 22.5 % of those seen in long-term acute care facilities, and 22.9 % of those seen in long-term care

facilities [56]. Okuwa identified three risk factors for lower extremity pressure ulceration in the elderly (1) low ankle-brachial index, (2) duration of time a patient is confined to bed, and (3) male gender. An ankle-brachial index was associated with a 2.27 LR (likelihood ratio) for developing a pressure ulcer [57]. The heel is one of the most difficult anatomical areas to effectively off-load pressure because of its small surface area and high tissue-interface pressure [58]. Specialized foam and sheepskin overlays were superior to standard hospital mattresses in preventing ulceration. However, none of the available bed surfaces provide complete pressure relief in the heel region [59]. Vanderwee and coinvestigators compared an alternating air overlay surface with a viscoelastic foam mattress. 447 patients admitted to acute care facilities in Belgium were randomly allocated to alternating air overlay surface and use of an air cushion when sitting or a viscoelastic foam mattress and use of the same air cushion when sitting plus patient repositioning every 4 h. More patients on the viscoelastic foam support surface plus turning program developed heel pressure ulcers than those managed on the alternating air surface overaly. The relationship remained after a logistic regression analysis that adjusted for length of stay, inpatient unit, method of assessment of pressure ulcer risk, and prevention protocol variables [60].

Many studies have been done comparing the effectiveness of pressure relief boots vs. standard hospital pillows for prevention of heel pressure sores. Tymec in 1997 evaluated 52 patients and found that patients using a boot-shaped air cushion were more likely to develop a heel pressure ulcer than patients using pillows [61]. In a comparison between heel protector made of siliconized hollow fibers with an ordinary pillow in 30 elderly patients (mean age 82 years), the pillow was more effective at reducing pressure on the heel [62]. The above studies suggested that pillows were more effective than boots for prevention of heel pressure ulcers. The types of pillows used in the above studies were standard hospital foam pillows. Heyneman compared a wedge-shaped cushion constructed from viscoelastic foam to a standard foam pillow. Patients managed with the wedge-shaped cushion had a significantly lower incidence of heel pressure ulcer than those managed with standard foam pillows (Fisher exact test $P = 0.03$) [63].

Boots are another category of heel protection devices. Junkin in 2009 suggests that boot-type devices are most likely to stay on the feet and that they support the foot in a neutral position, reducing the risk of foot-drop. There are two categories of boots: those with and those without a brace. The brace acts as an orthotic to prevent foot-drop and rotation of the leg. These devices are often referred to as podus or AFO (ankle-foot-orthosis) boots. Nevertheless, a wound care expert panel strongly supports observations that placing a brace on patients increases their risk of pressure ulcer. Orthotic boots are not an attractive alternative for prevention of heel pressure ulcer. Prevention of heel pressure ulcers relies on the physical therapists in fitting the boot with a brace (AFO) [46].

Boots have also been designed expressly for the purpose of preventing pressure ulcers on heels and ankle malleoli. These devices are made of foam, some are plastic filled with air, and some are fiber filled or made of a synthetic sheepskin material. Clinical experience reveals strengths and limitations associated with each product.

For example, foam boots tend to be warm and make it more difficult to move easily in bed but are relatively more inexpensive. Air-filled plastic boots are light, helping with bed mobility. The clinician must monitor and add more air if needed to maintain appropriate air pressure. Fiber-filled boots incorporate fiber wicks to take away heat and moisture. Some brands are covered with a slick surface that is easy to clean and assit patient bed mobility [46].

Overall Recommendations

The NPUAP recommends interventions including, but not limited to, turning patient every 2 h, avoiding wrinkles in the linen under a patient, avoiding excessive linen between the patient and the bed, and identifying and managing any sources of moisture. Special padding may be considered for the intra-operative period if the surgical procedure is expected to be long, or special mattresses can be ordered to ensure patients are immediately placed on a bed that minimizes risk of skin deterioration [46]. Rich summarized interventions recommended for prevention of pressure ulcers in 2009 article. Recommendations with clinical evidence included using an instrument such as the Braden or Norton scales, pressure-reducing devices such as overlays or mattresses, avoidance of exposure of skin to moisture from urinary or fecal incontinence, reduction of shear forces by limiting the head of the bed to an angle below 30°, and regular repositioning of immobile patients. Most of these recommendations are based on primarily expert opinion except for the use of pressure reducing devices which includes systematic reviews of randomized controlled trials [64].

Rich performed a cross-sectional study of 792 hospitalized patients over age 65 to examine adherence to pressure ulcer prevention guidelines and to determine the frequency and correlates of recording pressure ulcers in the patient record. The research nurse evaluated patients on hospital day 3 to determine the use of preventive devices, presence of pressure ulcers, and risk of pressure ulcers (Norton scale). Data on additional risk factors were obtained from the admission nursing assessment. They found that only 15 % of patients had any preventative devices in use at the time of the examination. 51 % of high-risk patients (Norton score $\leq$14) had a preventative device. High risk of pressure ulcers was associated with use of preventative devices (OR 41.8) whereas the type and stage of pressure ulcer were not. Documentation of a pressure ulcer was present for only 68 % of patients who had a pressure ulcer according to the researcher examination. Limitation of this study was that the data were collected between 1998 and 2001 and the emphasis on pressure ulcer prevention may have changed since that time [64]. A comprehensive pressure ulcer prevention protocol can be costly both in equipment needs as well as additional manpower. A summary of recommendations for pressure ulcer prevention includes:

1. Complete a Risk Assessment Instrument for Pressure Ulcers (Braden/Norton Scale) on admission and weekly in an inpatient setting. Complete a Risk Assessment Instrument on first visit as an outpatient and with any significant change in condition.

2. Use pressure reduction mattresses and cushions as indicated.
3. Minimize the amount of chronic moisture exposure from urinary or fecal incontinence or sweat.
4. Use of pressure reduction devices including pillows or boots for reduction of pressure on the heel.
5. Optimize nutritional status including protein intake and hydration.
6. Remind and/or assist patients in repositioning at least every 4 h and in high-risk patients every 2 h.

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Other Useful Pressure Ulcer Prevention Resources

AHRQ Toolkit–Preventing Pressure Ulcers in Hospitals. http://www.ahrq.gov/research/ltc/pressureulcertoolkit/

AHRQ Guideline Synthesis on Preventing Pressure Ulcers. http://www.guideline.gov/syntheses/synthesis.aspx?id=25078

National Pressure Ulcer Advisory Panel. http://www.npuap.org/

IHI How to Guide Reducing Pressure Ulcers. http://www.ihi.org/knowledge

Implementation Guide to Prevention of Hospital Acquired Pressure Ulcers (HAPU). http://hrethen.org/images/phocadownload/hapu_final_508.pdf