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An Integrated Approach to Pressure Ulcer Prevention and Treatment: The Role of Physical Activity, Nutrition, Care, and Modern Technologies

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ABSTRACT

Introduction: Pressure ulcers represent a significant healthcare challenge affecting patient outcomes and quality of life. This comprehensive review examines the integrated approach to pressure ulcer prevention and treatment, focusing on physical activity, nutrition, modern wound care technologies, and emerging therapeutic strategies.

Materials and Methods: Literature review was conducted using databases such as PubMed, NCBI, and Google Scholar, with search terms including "pressure ulcers", "physical activity", "nutrition", "wound care", "prevention", "modern technologies"

State of knowledge: Pressure ulcers develop when sustained pressure exceeds critical capillary pressures (arterial: ~32 mmHg; venous: 8-12 mmHg), leading to tissue ischemia and necrosis. Physical activity demonstrates significant benefits in wound healing through immune modulation, improved circulation, and enhanced tissue regeneration. Nutritional interventions, particularly protein supplementation (24% vs. 14% protein), show improved healing rates. Modern wound care technologies, including specialized dressings and emerging therapies like hyperbaric oxygen and stem cell treatments, demonstrate promising results. Prevention strategies incorporating risk assessment tools, proper positioning techniques, and skin care protocols significantly reduce pressure ulcer incidence.

Conclusions: An integrated approach combining physical activity, proper nutrition, and advanced wound care technologies offers the most effective strategy for pressure ulcer prevention and treatment. Novel diagnostic and therapeutic approaches, including electrical impedance analysis and stem cell therapy, show promise for improving outcomes. Further research is needed to validate emerging technologies and establish standardized treatment protocols.

Keywords: "pressure ulcers", "physical activity", "nutrition", "wound care", "prevention", "modern technologies".

INTRODUCTION

Pressure ulcers (PUs) are a serious health problem, particularly among hospitalized patients, the elderly, and those who are immobile for long periods. It is estimated that their prevalence in hospitals ranges from 5% to 15%, but in long-term care patients, the risk increases to 23-27% [1]. A higher incidence is also observed in intensive care units (ICU), reaching up to 21.5%. Older individuals are particularly at risk, with the highest percentage of cases-up to 29%- reported among patients aged 71–80 years [2, 3]. Particularly at-risk groups include patients with neurological disorders, for whom the risk of developing pressure ulcers throughout their lifetime ranges from 25% to 85%, as well as individuals with spinal cord injuries and critically ill patients requiring mechanical ventilation [4,5,6,7].

A frequently utilized instrument for assessing the risk of pressure ulcers is the Braden Scale (widely available online), which allows for the early identification of patients requiring special care. This scale takes into account six factors influencing the risk of pressure ulcer development, each of which is rated on a scale from 1 to 4 points. The total score can range from 6 to 23 points, with a score of ≥19 points indicating minimal risk, 15–18 points indicating moderate risk, 13–14 points indicating high risk, and ≤12 points indicating very high risk of pressure ulcer development [8, 9].

Studies indicate that the presence of PUs among patients hospitalized in ICU is associated with a prolonged ICU stay and a higher risk of mortality. Patients with pressure ulcers are hospitalized for an average of 13 days in the ICU, which is significantly longer compared to patients without pressure ulcers (around 3 days), and the mortality risk for these patients is nearly twice as high compared to those without this condition [10].

Pressure ulcers most commonly occur in the sacral area, ischial tuberosities, and greater trochanter – accounting for about 70% of cases. Another 15–25% are located on the lower extremities, mainly on the heel and lateral ankle. However, they can develop in any area exposed to prolonged pressure, including the elbows, ears, nose, chest, and back [1].

In 2016, the National Pressure Ulcer Advisory Panel (NPUAP) introduced new terminological guidelines, adopting the term "pressure injury" as the preferred term to better reflect all forms of tissue damage, including early stages before skin breakdown. The organization also officially changed its name to the National Pressure Injury Advisory Panel (NPIAP) [11].

The classification of pressure injuries is divided into six categories: Stage 1 to Stage 4, Deep Tissue Pressure Injury (DTPI), and Unstageable Pressure Injury. Each category describes the severity of tissue damage, ranging from non-blanchable redness in Stage 1 to full-thickness wounds with exposed bone or muscle in Stage 4. Deep tissue injuries, which may not be immediately visible, and unstageable injuries, where the extent of damage is obscured, are also included. This system helps in the accurate assessment, treatment, and prevention of pressure injuries (Tab.1.).

STAGE	CHARACTERISTIC
Stage 1	Intact skin with localized non-blanchable redness. The area may be painful, warmer or cooler, firmer or softer than the surrounding tissue.
Stage 2	Partial-thickness skin loss involving the epidermis and/or dermis. May appear as an open, shallow wound with a pink wound bed or as an intact or ruptured blister. No slough or deeper tissue damage present.
Stage 3	Full-thickness skin loss with visible subcutaneous tissue damage but without exposed bone, tendon, or muscle. May include slough, tunneling, or undermining of wound edges.
Stage 4	Deep tissue damage involving full-thickness skin loss with exposed bone, tendon, or muscle. Often accompanied by slough, eschar, or tunneling.
Deep Tissue Pressure Injury (DTPI)	Persistent dark red, purple, or blood-filled blister indicating deep tissue injury. Skin may remain intact initially, but underlying damage may progress rapidly.
Unstageable Pressure Injury	Full-thickness tissue loss where the wound bed is covered with slough (yellow, green, brown) or eschar, making it impossible to determine the depth of the injury until the wound is debrided.

Table 1. Stages of pressure ulcers along with their characteristics.

MATERIALS AND METHODS

The literature review was carried out using PubMed, NCBI, and Google Scholar to ensure access to reliable and up-to-date sources. The search process involved keywords such as "pressure ulcers," "physical activity," "nutrition," "wound care," "prevention," and "modern technologies." To broaden the scope, related terms were also considered. Priority was given to scientific articles, research reviews, and recent studies that provide valuable insights into the prevention and treatment of pressure ulcers.

In 2016, the National Pressure Ulcer Advisory Panel (NPUAP) introduced new terminological guidelines, adopting the term "pressure injury." However, for the purposes of this article, the older term "pressure ulcers" will be used.

STATE OF KNOWLEDGE

1. Risk factors, pathogenesis of pressure ulcers, and their complications

Pressure ulcers (PUs) develop due to sustained pressure exceeding critical capillary pressures (arterial: ~32 mmHg; venous: ~8–12 mmHg), impairing perfusion and leading to ischemia, hypoxia, and necrosis. These lesions typically form over bony prominences, where pressures can be 3–5 times higher internally than at the skin surface, affecting deeper tissues first. The heel's unique structure exemplifies this mechanism: fibrous septa anchor skin to bone, creating compartments of subcutaneous fat prone to ischemic injury, akin to compartment syndrome. Damage begins in metabolically active tissues, such as the panniculus carnosus muscle (average thickness: 1.52 mm, 8.2% of heel thickness) and subcutaneous fat, which exhibit early necrosis under pressure. Shear and friction forces exacerbate vascular distortion and tissue hypoxia, while moisture-induced maceration further weakens the skin's defenses. Clinically, superficial ulcers arise from friction and shear, while deeper lesions involve prolonged isolated pressure, often concealed by intact skin until advanced necrosis becomes evident. Reperfusion injury compounds ischemic damage through reactive oxygen species and inflammatory responses. Experimental models confirm that cycles of ischemia and reperfusion cause more damage than continuous ischemia. These mechanisms underscore the multifactorial nature of pressure ulcers and highlight the need for targeted prevention and intervention strategies [1, 12].

The primary risk factors include impaired mobility or activity, compromised perfusion (including diabetes, hypoalbuminemia, and vascular disease), and pre-existing pressure ulcer status. Secondary contributors, though less consistently predictive, comprise skin moisture levels, advanced age (with patients ≥70 years having progressively higher risk up to an OR of 5.2 for those ≥90 years), hematological abnormalities (low hematocrit or hemoglobin levels), nutritional deficits (hypoalbuminemia), and general health status. Limited evidence suggested a role for race or gender in pressure ulcer risk [13].

Fogerty et al. [14] conducted a study, reviewing risk factors for pressure ulcers in acute care hospitals. This study utilized data from the 2003 Nationwide Inpatient Sample (NIS) to evaluate risk factors for pressure ulcers in acute care hospital settings. The incidence of pressure ulcers was reported at 1.43% (94,758 cases out of 6,610,787 discharges). Multivariate logistic regression identified advanced age, African- American race, and various clinical comorbidities as significant predictors. Patients aged over 75 years demonstrated the highest risk, with an odds ratio (OR) of 12.63, compared to the reference group aged 18–39 years. Similarly, African

American patients exhibited a higher likelihood of pressure ulcer diagnosis, with ORs exceeding 2 across all age groups. Among comorbid conditions, gangrene presented the highest risk (OR 10.94), followed by septicemia (OR 9.78), osteomyelitis (OR 9.38), and nutritional deficiencies (OR 9.18). The findings underscore the importance of targeted preventive measures for high-risk groups, particularly the elderly and those with systemic infections or compromised skin integrity.

Pressure ulcers in critically ill patients significantly contribute to adverse outcomes, including heightened risk of infections due to compromised skin integrity and antimicrobial resistance, extended hospitalization durations (up to fivefold increase), elevated treatment costs driven by specialized wound care requirements, and increased mortality risk (4.5 times higher) due to associated complications such as systemic infections. Furthermore, patients experience profound physical suffering, exacerbated by pain during wound management and increased dependency on caregivers, which also induces psychological stress among family members [15]. Additional complications, including incontinence, polypharmacy, and frailty, further diminish the functional reserve, making PUs a marker of deteriorating health [16].

2. Mechanisms through which physical activity facilitate wound healing

Physical activity has a beneficial effect on the wound healing process through a number of physiological and immunological mechanisms. Clinical studies have provided evidence for accelerated wound healing as a result of regular exercise in humans [17, 18, 19, 20].

One of the key mechanisms is the modulation of the immune response. Physical exercise affects the polarization of macrophages, which play an important role in the wound healing process. Under physiological conditions, macrophages can adopt a pro-inflammatory M1 phenotype or an anti-inflammatory M2 phenotype. Studies have shown that regular physical activity promotes a shift in the balance towards the M2 phenotype, which supports angiogenesis and inhibits excessive inflammation [17].

Moreover, exercise increases the cytotoxicity of NK (natural killer) cells against cancer cells in vitro. In a study on older women, a 10-week aerobic exercise program resulted in increased cytotoxic activity of NK cells. This may have an indirect effect on wound healing by improving overall immunity [17, 21].

Physical activity improves blood circulation and tissue perfusion, which is crucial for delivering oxygen and nutrients to the healing wound. Increased angiogenesis accelerates the tissue regeneration process [17, 22].

Exercise also modulates the pro- and anti-inflammatory balance in the body. Regular physical activity can lower the levels of inflammatory mediators, such as prostaglandin E2 (PGE2), which promotes wound healing [17, 23].

Key evidence for the positive effect of exercise on wound healing comes from a study conducted by Emery and colleagues on humans. In a randomized controlled trial, a group of older adults (mean age 61 years) was assigned to a 3-month aerobic exercise program or a control group. One month after the start of the intervention, all participants underwent an experimental wound procedure on their arm. Exercise participants achieved significant improvements in cardiorespiratory fitness. Most importantly, wounds in the exercise group healed significantly faster (mean 29.2 days) compared to the control group (38.9 days) [18].
This study also demonstrated the effect of exercise on neuroendocrine function. Exercise participants experienced increased cortisol reactivity in response to exercise testing after 3 months of training. This suggests that exercise may improve the body's ability to regulate stress response, which may have an indirect effect on the wound healing process [18].

3. Physical activity in the prevention and treatment of pressure ulcers

Physical exercise can serve as an effective non-pharmacological intervention to reduce the risk of foot ulcers, a condition associated with high peak pressures, particularly in individuals with diabetic neuropathy (DPN) [24, 25]. Ferreira et al. [26] evaluated the effectiveness of a web-based foot-ankle exercise program designed to improve DPN-related outcomes, gait biomechanics, and functional measures. A total of 62 participants with DPN were randomly assigned to either a control group (CG; n = 31), which received standard care, or an intervention group (IG; n = 31), which received standard care plus a 12-week foot and ankle exercise program delivered via web-based software (SOPeD). The study followed participants for 24 weeks in total.

The exercise program [26] consisted of three sessions per week for 12 weeks, with each session lasting approximately 20–30 minutes. It included eight exercises targeting intrinsic and extrinsic foot muscles as well as ankle-foot joints, incorporating warm-ups, arch stretching, strengthening, and functional activities such as balance and gait training. SOPeD offered 39 distinct exercises with 104 variations, accommodating different difficulty levels. Participants could progress to a higher level, maintain their current level, or regress to an easier stage based on their performance and effort.

While symptoms and severity of DPN remained unchanged after the exercise program, participants in the IG demonstrated significant improvements compared to the CG. These included greater functional reach at 12 weeks, improved foot function, reduced foot pain, and increased plantar flexion during push-off at 24 weeks. Regarding plantar pressure during gait, forefoot pressure decreased in the IG after 12 weeks compared to baseline but increased at 24 weeks compared to the CG.

The 12-week web-based foot and ankle exercise program was feasible, well-accepted, and safe, with minimal adverse events such as delayed-onset muscle soreness and foot cramps. Although DPN-related outcomes were not directly altered by the SOPeD program, modest improvements were observed in foot pain, function, functional reach, plantar pressure distribution, and plantar flexion during gait, particularly at the 24-week follow-up.

The efficacy of similar exercise programs was evaluated in a meta-analysis by van Netten et al. [27]. They observed that in individuals at risk of foot ulceration, an 8–12-week foot-ankle exercise program is unlikely to prevent or cause diabetes-related foot ulceration. However, such a program is likely to enhance the range of motion in the ankle joint and first metatarsophalangeal joint, as well as improve signs and symptoms of neuropathy.

Nwankwo et al. [28] demonstrated that active physical exercise accelerates wound healing in patients with diabetic foot ulcers. The study recruited 61 patients, including 31 men and 30 women with diabetic foot ulcers, who were randomly assigned to one of two groups: the intervention group, which received aerobic exercise on a stationary bicycle ergometer, or the control group, which only received routine care without exercise. Participants attended the clinic three times a week, and both groups were assessed for baseline measurements, including BMI, fasting blood glucose, total cholesterol, and wound size. Follow-up evaluations were conducted every two weeks over a 12-week period.

The aerobic exercise regimen began at 60% of the maximum heart rate (HR) determined during an exercise test, gradually increasing to 85% of that value over the course of the 12 weeks. The researchers found that participants in the intervention group experienced a significant reduction in wound size compared to the control group following the intervention.

Promising results were also reported by Eraydin et al. [29], who, in their randomized trial, demonstrated that ulcer areas significantly decreased in the intervention group compared to the control group across three follow-up measurements. Additionally, the reduction in diabetic foot ulcer area was more pronounced in individuals who engaged in higher levels of physical activity. In the study, patients in the intervention group (n=33) received standard wound care combined with daily foot exercises for 12 weeks, while the control group (n=32) received standard wound care without any exercise intervention. The exercise regimen began with seated exercises and progressed to standing exercises once the wounds healed. The program included range-of-motion exercises such as plantar flexion, dorsiflexion, inversion, eversion, ankle circles, and toe plantar and dorsiflexion. Each session involved at least 5 to 10 exercises with 10 to 15 repetitions per movement. Weight-bearing exercises were avoided to prevent undue stress on the affected areas.

What about passive exercises? Jørgensen et al. [30] investigated this through an 8-week training program. The study included 21 patients who were randomly assigned to either a control group or an intervention group undergoing passive movement exercises. However, the passive movement intervention demonstrated a non-significant difference in the healing of foot ulcers.

4. Diet as a supportive therapy in the treatment of pressure ulcers

There are numerous reports on the impact of diet on many aspects of pressure ulcer treatment. Studies indicate that appropriate nutritional support can play a significant role in both preventing and treating pressure ulcers [31, 32].

Stratton et al. in their meta-analysis showed that the use of nutritional supplementation (oral or enteral) significantly reduces the incidence of pressure ulcers in high-risk patients by approximately 26% (odds ratio 0.74, 95% CI 0.62-0.88) compared to patients receiving standard care [32, 33].

Studies suggest that increased protein intake may accelerate the healing of pressure ulcers. In one study involving 28 malnourished nursing home residents with existing pressure ulcers, an improvement in wound healing rate was observed in individuals receiving nutritional supplements containing 24% protein compared to the group receiving formulas with 14% protein over a period of 8 weeks [32,34].

Langer et al. conducted a review encompassing 33 randomized clinical trials involving 7920 participants. Among these, 24 studies focused on the treatment of existing pressure ulcers. They provide a range of information related to the role of diet in treating pressure ulcers. However, the studies included in the systematic review did not focus on the impact of special diets (e.g., high-protein diet or vegetarian diet) on the incidence and healing of pressure ulcers [31].

Firstly, supplements containing energy, protein, and micronutrients may slightly increase the number of healed pressure ulcers compared to a standard diet (RR 1.45, 95% CI 1.14 to 1.85; 3 studies, 577 participants, low certainty of evidence) [31, 35, 36].

Secondly, collagen supplements probably improve the mean change in pressure ulcer area compared to placebo (MD 1.81 cm^2 smaller, 95% CI 3.36 smaller to 0.26 smaller; 1 study, 74 participants, moderate certainty of evidence) [31, 37].

The authors also state that supplements containing arginine and micronutrients may not increase the number of healed pressure ulcers, but may slightly reduce the pressure ulcer area (MD 15.8% lower, 95% CI 25.11 lower to 6.48 lower; 2 studies, 231 participants, low certainty of evidence) [31, 38, 39].

The role of arginine supplementation in the treatment of pressure ulcers is also addressed in a randomized controlled trial by Desneves et al., in which they evaluated the effect of a supplement containing arginine, vitamin C and zinc on pressure ulcer healing. Patients receiving this specialized supplement showed a 2.5-fold greater statistically significant improvement in pressure ulcer healing, assessed using the PUSH tool (Pressure Ulcer Scale for Healing), compared to the control group [32,40].

5. Dressings used for treating pressure ulcers

Pressure ulcers also known as bedsores, necessitate the use of suitable dressings to support healing, shield the wound, and address issues such as exudate, pain and infection. With numerous effective options available, selecting the most appropriate one is crucial. The following is a brief overview of common dressing types, each tailored to specific wound care requirements. These options aim to balance advantages like absorption, protection, and healing facilitation with considerations such as practicality and ease of application.

Foam dressings are soft, absorbent and help maintain a moist wound environment while cushioning the area to relieve pressure. They are highly effective at absorbing moderate to heavy exudate and come in adhesive and non-adhesive options. Additionally, foam dressings support autolytic debridement. However, they are not appropriate for dry wounds and may need a secondary dressing when using non-adhesive forms [41, 42, 43, 44, 45, 46].

Hydrocolloid dressings consist of gel-forming agents combined with a backing that fosters a moist wound environment. These dressings facilitate autolytic debridement, are suited for light to moderate exudate, can remain in place for several days and have an occlusive characteristic. They are versatile, able to conform to joints or fill wound cavities and provide waterproof protection against external contaminants. However, they are less suitable for heavily exuding or infected wounds, can adhere to the wound bed thus causing trauma during removal. Hydrocolloid dressings also generate odor and discomfort. Biodegradable and breathable, hydrocolloid dressings are widely utilized for managing pressure ulcers [41, 43, 44, 45, 46, 47].

Alginate dressings, derived from seaweed, are highly absorbent and form a gel when in contact with wound fluid. They are ideal for managing heavy exudate, conform to the wound bed, and support hemostasis in bleeding wounds due to their calcium ion content. Additionally, they can be easily removed without harming the tissue. However, they require a secondary dressing for secure placement, are unsuitable for dry wounds or those with minimal exudate and may lead to maceration of surrounding skin if not properly managed. These dressings are particularly effective for wounds with significant exudate [41,43,44,45, 46, 47].

Hydrogel dressings, composed of up to 96% water, are designed to hydrate and cool dry wounds. They are well-suited for dry or necrotic wounds, stimulate autolytic debridement, alleviate pain and offer a soothing effect. Available in sheet, gel, or impregnated forms, these dressings have limited absorption capacity, making them unfit for wounds with heavy exudate. They require frequent changes and may cause maceration of the surrounding skin. Hydrogel dressings are particularly effective in accelerating the healing of arterial ulcers and surgical wounds [41, 43, 44, 45, 46, 48].

Silver-impregnated dressings, infused with silver to provide broad-spectrum antimicrobial properties, are effective for treating superficially infected wounds or those at risk of infection. Silver ions work by disrupting bacterial cell walls, interfering with DNA synthesis and deactivating bacterial enzymes. However, a potential drawback is that oxidized silver may stain the skin. Additionally, silver ions are unable to penetrate deep wounds and prolonged use of iodine-based products raises concerns about systemic adverse effects [41,43,44,46, 47].

Protease-modulating dressings are designed for chronic wounds with elevated protease activity, which impairs the healing process. Subtypes include collagen/ORC dressings, which combine collagen with oxidized regenerated cellulose to neutralize excess proteases and superabsorbent dressings, which control high exudate levels while regulating protease activity. By reducing protease activity, these dressings promote healing, effectively moderate exudate and minimize inflammation, therefore enhancing patient comfort. However, their use is limited to wounds with high protease activity and regular wound assessments are necessary to evaluate the need for continued therapy [41, 42, 49, 50].

Transparent film dressings are thin, flexible adhesive sheets that maintain a moist environment while serving as a protective barrier. They are permeable to water vapor and oxygen but impermeable to water and microorganisms. These dressings enable visual monitoring, are waterproof, support autolytic debridement, and are easy to implement. However, they are not suitable for wounds with moderate to heavy exudate, can cause trauma when removed from fragile skin and may cause maceration or trapping infection. Transparent film dressings are optimal for shallow wounds, split-thickness skin graft donor sites, minor injuries, intravenous access sites and as secondary dressings [41,43,44,45,46, 47].

6. Pressure sores care.

Care for pressure ulcers requires specialized knowledge, careful attention, and consistency. Pressure ulcers, as challenging skin and tissue injuries, demand particular care and focus. Proper management of pressure ulcers is essential for effective healing.

The best solution for cleaning pressure ulcers is saline. Other agents, such as povidone-iodine, can damage tissues. Hydrogen peroxide or Dakin’s solution (sodium hypochlorite) do not harm tissues but should not be used when there are no signs of wound infection [51].

Wound cleaning can also be performed with water and unscented soap that does not contain antibacterial agents and has a pH consistent with skin (4.5–5.7) [6].

Debridement is an important step in wound care. The term *debridement* refers to the removal of all elements from the wound that inhibit or delay healing, such as necrotic tissue, biofilm, pus, bone fragments, hematomas, or infected tissues [52]. This procedure not only facilitates wound healing but also reduces the risk of infection, limits exudate, and eliminates unpleasant odors often associated with pressure ulcers. Moreover, it allows for a proper assessment of the wound size and classification into the correct stage [53]

The intervention can be performed using several methods, including surgical debridement (using a scalpel, razor blade, or curette) [54], mechanical debridement (using gauze, cloths, sponges, or irrigation), enzymatic debridement, or biological debridement.

Autolytic debridement is a process that occurs naturally during the healing of most wounds with the involvement of phagocytes and the body’s own proteolytic enzymes. This process can be supported by dressings, such as hydrocolloid dressings, which provide a moist environment conducive to autolysis [55].

Enzymatic debridement involves the use of ointments or gels containing collagenase produced by *Clostridium histolyticum* or bromelain, extracted from the stem of pineapple. Bromelain, a group of proteases, has been proven to be a safe, effective, and rapid method for cleaning wounds, including those caused by sunburn [56, 57]

Biological debridement, or Maggot therapy, utilizes the larvae of the *Lucilia sericata* fly. These larvae not only clean the wound but also produce antibacterial compounds, such as lucifensin, lucifensin II, and lucilin, which inhibit bacterial colonization by organisms like

Staphylococcus aureus or *Pseudomonas aeruginosa* [58]. It is estimated that the optimal application involves approximately 5 larvae per 1 cm^2 of the wound, with a recommended duration of about 72 hours [59].

Monitoring infections is extremely important. Pressure ulcers without signs of infection, even those with necrosis, do not require the use of antibacterial agents. Topical antibiotic treatments have limited efficacy, and intravenous antibiotics are recommended only for severe cellulitis, bone infections, or systemic symptoms. Antibiotics should be discontinued once symptoms subside. In cases of osteomyelitis, the removal of infected bone tissue and coverage with well-vascularized, healthy tissue may be necessary [60].

When dressing pressure ulcers with gauze, the gauze should completely fill the wound and be changed every 6–8 hours. Other dressings used in pressure ulcer therapy are described above [51].

7. Quality of Life in patients with pressure ulcers and strategies for their prevention

The issue of pressure ulcers plays a particularly significant role in palliative care, as their occurrence worsens patients' quality of life, adds to their suffering, and exacerbates the limitations caused by the underlying disease. Pressure ulcer prevention can involve practices such as assessing the risk of developing pressure ulcers using standardized scoring scales, frequently repositioning immobile patients (every 2-3 hours), using mattresses with variable pressure settings, and employing devices that reduce pressure (such as cushions, foam pads, and rolls). Proper skin care is also crucial in minimizing the risk.

The condition of the patient's skin, nutritional status, and the progression of the underlying disease play significant roles in pressure ulcer development. Identifying at-risk patients and implementing preventive measures should begin as soon as nursing care starts. Tools such as scoring systems, for example, the Norton Scale, can aid in evaluation. This scale assesses five parameters: physical condition, mental state, activity level, mobility, and continence (urinary and fecal). Each parameter is rated on a 4-point scale, from 1 (very poor) to 4 (good). According to Stechmiller et al., the sensitivity and specificity of the Norton Scale range from 73–92% and 61–94%, respectively [61].

A pressure ulcer can form after as little as 2-4 hours of continuous pressure [62]. Relieving pressure through supportive surfaces such as mattresses, overlays, bed systems, and gel pads helps reduce the strain on the skin. Pressure is minimized when the body's weight is distributed over a larger contact area (body mass/contact surface area). The angle of bed elevation is an important preventive factor. The bed's headrest should be positioned at the lowest possible elevation angle, as higher angles increase shear and friction forces. The 30° lateral tilt position, achieved by supporting the patient's buttocks and legs with pillows minimizes pressure on bony prominences by reducing direct contact with the support surface. According to a large, randomized trial demonstrated by Z. Moore et al. showed that adopting the 30° tilt with repositioning every 3 hours reduced the incidence of pressure ulcers by over 70% compared to the 90° lateral position with 6-hour repositioning, after just 28 days [63]. Support equipment should meet required certifications and be used according to its specifications. Commonly available items such as pillows, blankets, or inflatable rolls can also be used for offloading. Anti-decubitus mattresses vary widely and can be utilized in both short- and long-term care. Examples include alternating pressure mattresses, air-fluidized beds, and bubble mattresses. Regular repositioning of patients remains essential. Devices such as lifts can assist in evenly distributing pressure during transfers or when changing a patient's position [64].

Skin care guidelines emphasize the importance of regular assessment (at least twice daily), with a focus on areas at higher risk of damage. Daily skin cleansing with warm water (below 37°C) and mild cleaning agents, such as soap with an acidic pH close to the skin's natural level (approximately 5.5), is recommended. After washing, the skin should be gently dried, particularly in areas prone to moisture retention, such as under the breasts, skin folds, and intimate areas [64]. Additionally, protecting healthy, intact skin using specialized barrier products, as well as those that improve elasticity and firmness while hydrating, softening is advised[60].

The negative impact of pressure ulcer complications can also affect the patient's mental health. Prolonged immobility and dependence on others can lead to depression and a sense of low self-worth. The situation is further worsened by the presence of foul-smelling, slowly healing wounds [65]. In this study Qian L. analyzed the psychological consequences of pressure ulcers and to develop effective strategies for alleviating these effects and improving overall well-being. The study was conducted in post-acute care facilities in Beijing from March 2022 to December 2023. A total of 431 participants were involved, including patients with pressure ulcers and their primary caregivers. The methods used included structured questionnaires and semi-structured interviews, which allowed for the assessment of demographic, clinical, and psychological parameters such as quality of life, anxiety, stress, and depression. The results of the study revealed that both patients and caregivers experienced significant psychological impact, with caregivers showing lower quality of life and higher levels of anxiety, depression, and stress. Additionally, a significant positive correlation was found between the degree of psychological stress and the severity of pressure ulcers [65].

The prevention of pressure ulcers is a very important part of the therapeutic process for hospitalized patients. It is essential to be aware of the risk factors in order to determine the appropriate course of action, which can be aided by the use of relevant scoring scales. Psychological support in the case of pressure ulcers is an important element of comprehensive care for patients with this condition.

8. Modern approaches in the treatment of pressure ulcers

Apart from traditional diagnostic and therapeutic methodologies for pressure ulcers, advancements in technology have given rise to novel approaches. It is widely known that the diagnostic process is based on physical examination, however, visible skin lesions do not always correlate with underlying damage and inflammation. Another challenge posed by visual examination is the issue of skin tone variability among patients, which can impede the proper assessment of lesions [66]. In their study, Congo Tak-Shing Ching et al. [67] revealed a change in electrical impedance at and around ulcers in comparison with healthy tissue. The cell membrane of necrotic cells in the injured area are damaged, allowing fluid flow between the intracellular and extracellular spaces. The volume of the extracellular space increases, which in turn increases the flow of low-frequency current in comparison with tissue with normal extracellular space. The authors of the study suggest that impedance analysis has significant potential for screening purposes, as it can detect early lesions, does not require much experience from medical personnel, and provides immediate results.

A growing amount of studies focus on the development of more effective treatment methods. V. Procházka et al. [68] conducted a study which involved 96 participants suffering from critical limb ischaemia and foot ulcers. Patients were divided into two groups: an intervention group (group one) which received local application of autologous bone marrow stem cells (ABMSC) concentrate, and a control group which received standard care. The procedure involved the collection of bone marrow and isolation of stem cells from the aspirate. The samples were then processed, and the final bone marrow concentrate was applied to the ischemic limb, posterior and anterior tibial arteries.The results showed that the intervention group required fewer major limb amputations (21%) (MLA) than the control group (44%). Furthermore, MLA procedures were required in the group one patients who suffered from lymphopenia and thrombocytopenia in BMC at the time of treatment.The intervention group reported a reduction in pain 72 hours after treatment initiation using the EQ-50 quality of life questionnaire. The study demonstrated that patients who healed exhibited a favourable response to the treatment, with a significant reduction in pain levels over time. In contrast, participants who did not heal exhibited initial low platelet and CD34+ cell levels in the bone marrow. These findings suggest a potential mechanism by which stem cell treatment can enhance ulcer healing.The authors emphasise the need for further research in this area, highlighting the potential for stem cell treatment to advance wound healing and contribute to medical advancement.

Le Ma et al. [69] examined the influence of hyperbaric oxygen (HBO) therapy on the healing of ulcers over a short period of time, as well as the safety of the procedure. The intervention group underwent 20 sessions of HBO (five days a week for two weeks), which involved the inhalation of 100% oxygen within a pressurised hyperbaric chamber. The protocol consisted of 15 minutes of compression time, three 30-minute intervals of HBO separated by 5 minutes of room air, and then 15 minutes of decompression time. The results showed that transcutaneous oxygen pressure (TcPo20) improved among the intervention group in comparison with the control group. Furthermore, the researchers observed a significant decrease in ulcer size, with a 42.4% reduction in the HBO group and 18.1% reduction in the usual care group after a period of two weeks. Accumulation of reactive oxygen species (ROS) was a major concern during the study. Samples of ulcers were obtained at the 10th and 20th sessions for further examination. Oxidative stress was measured by the level of malondialdehyde (MDA), an oxidative stress marker, and the expression of antioxidant enzymes: superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx). Following a two-week period, the MDA level, SOD-1, and CAT expression were found to be elevated in the intervention group when compared to the control group. However, no significant changes were observed in GPx expression. The HBO treatment was found to enhance wound healing, with a significant decrease in ulcer size when compared to the usual care group. However, the progression of ROS accumulation poses a significant limitation for the procedure application in long-term therapy, and further research is required to study its safety.

Another form of therapy that is being currently studied is phototherapy. A thorough literature review was conducted by Chiehfeng Chen et al. [70] in order to explore the clinical usefulness of the procedure. Majority of the reviewed studies had low quality and insufficient evidence, with small group of participants and probable bias of the publications which were frequently sponsored by product manufacturing companies which undermine the results. The studies were unsatisfactory, and the topic needs further research.

A group of researchers [71] created a fixation device with the objective of preventing pressure injury related to endotracheal intubation. A randomised controlled trial was conducted in which the efficacy of the novel device was examined. The study included 51 patients in the intervention group, in which the fixation device was used, and 54 patients in the control group. The eligible criteria were as follows: Intensive care unit (ICU) admission and need for intubation/mechanical ventilation for more than 48 hours. The results demonstrated that participants with the fixation device developed intubation-related pressure injuries in 7.8% of cases, while in the control group this figure was 33.3%. The study findings indicated that the novel device could be beneficial for patients requiring prolonged intubation/mechanical ventilation.

In conclusion, novel methods of diagnosing and treating pressure ulcers are continuously being developed and require further research. The results of many studies are bringing us closer to more innovative solutions that have the potential to revolutionise the approach to pressure ulcers and provide better care for patients.

CONCLUSIONS

The comprehensive approach to pressure ulcer prevention and treatment requires the integration of several key elements. Regular physical activity accelerates wound healing through immune modulation, improved circulation, and enhanced tissue regeneration. Exercise programs targeting foot and ankle movements can reduce the risk of ulceration, particularly in patients with diabetic neuropathy. Nutritional supplementation reduces pressure ulcer incidence by approximately 26% in high-risk patients. Higher protein intake (24% vs 14%) demonstrates improved healing rates in pressure ulcer treatment. The selection of appropriate dressings should be tailored to wound characteristics. Regular wound cleansing, proper debridement techniques, and infection control are essential components of effective pressure ulcer management. Modern diagnostic tools like electrical impedance analysis show promise for early pressure ulcer detection. Novel therapeutic approaches, including stem cell therapy and hyperbaric oxygen treatment, demonstrate encouraging results in wound healing acceleration. Pressure ulcers significantly impact patients' psychological well-being and quality of life.

Comprehensive care should incorporate psychological support alongside physical treatment. Prevention strategies utilizing risk assessment tools, proper positioning techniques, and skin care protocols significantly reduce pressure ulcer incidence. Further research is needed to validate emerging technologies and establish standardized treatment protocols. The integration of physical activity, proper nutrition, and advanced wound care technologies offers the most effective strategy for pressure ulcer prevention and treatment.

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