Open Access

Recent Progress in Nutrition

LIDSEN Publishing Inc.

Perspective

Nutrition for Healing Acute and Chronic Wounds: Current Practice, Recent Research Findings, and Insights for Improving Care

Mary Beth Arensberg [1], Bethan E. Phillips [2], Kirk W. Kerr [1, *]

1. Abbott Nutrition Division of Abbott, Columbus, Ohio, USA; E-Mails: mary.arensberg@abbott.com; kirk.kerr@abbott.com
2. Centre of Metabolism, Ageing and Physiology (COMAP), MRC-Versus Arthritis Centre for Musculoskeletal Ageing Research (CMAR), NIHR Nottingham Biomedical Research Centre (BRC), School of Medicine, University of Nottingham, Derby, UK; E-Mail: Beth.Phillips@nottingham.ac.uk

* **Correspondence:** Kirk W. Kerr; E-Mail: Kirk.kerr@abbott.com

Academic Editor: Arrigo F. G. Cicero

Special Issue: Clinical Nutrition: Recent Advances and Remaining Challenges in Aiding Acute Surgical or Traumatic Wound Healing

Recent Progress in Nutrition
2024, volume 4, issue 3
doi:10.21926/rpn.2403014

Received: March 20, 2024
Accepted: September 02, 2024
Published: September 10, 2024

Abstract

Wound prevalence is increasing as the global population ages. Older adults are at risk of wounds from falling and from other medical conditions that contribute to wound development and slowed healing (e.g., diabetes, cancer, chronic infections); they often experience health conditions that necessitate surgery and therefore post-surgical healing. Poor nutrition status, which includes deficiencies in macro- and micronutrients, is recognized as a key contributor to impaired wound healing in older adults. As such, the need for nutrition-focused wound care is also increasing. This *Perspective* review provides a framework for considering the links between nutrition, wounds, and healing. We start with a review of factors related to high incidence and prevalence of wounds in older adults, including inadequate nutrition. Nutrition interventions enhancing wound healing are also described as well as insights into strategies and tools for including nutrition as part of overall quality wound

care, particularly for older adults. To meet the growing challenge of wound healing, professionals across care settings need to implement comprehensive and holistic wound-care strategies to benefit patient and healthcare-system outcomes. Nutrition is a critical intervention for these strategies.

Keywords
Nutrition; nutrition interventions; quality wound care; wound healing

1. Introduction

Wound healing is a significant health-related challenge in the 21st century [1]. From a global perspective, chronic wounds of mixed etiologies have a pooled prevalence of 2.21 per 1000 population [2]. With ever-improving public health programs and medical treatments, human longevity has markedly extended over the last century, and as such, the global population of older adults (>60 years) is growing at a remarkable rate (i.e., from 1 billion in 2019, expected to double to 2.1 billion by 2050) [3]. Accordingly, wound prevalence is increasing, as older adults are at greater risk of wound injuries from both falling [4], and from medical conditions that contribute to wound development and slowed healing (e.g., diabetes) [5, 6], as well as from health conditions that necessitate surgery and therefore post-surgical healing [7, 8]. For example, a United States (US) study of older adults found that 15% of individuals required care for wounds or wound-related infections in a year [9]. The financial costs of wound care are high, raising the focus on lowering risk and improving care as strategies to achieve cost savings [6]. In the US, total public spending for all wound types in older adults was estimated to be at least $28 billion annually [9]. Importantly, disparities in both wound prevalence and in wound healing outcomes have been associated with age, race/ethnicity, and care setting [10-12].

Some factors related to wound healing, such as nutrition, are potentially modifiable factors that can be improved to lead to better wound outcomes, particularly for older adults [13-15]. To highlight links between nutrition, wounds, and healing, this *Perspective* review paper describes factors related to high wound incidence, prevalence, and poor healing in older adults, including inadequate nutrition. We specifically outline nutrition interventions shown to enhance wound healing and those supported with recent research findings and implemented in current practice. We also provide insights into effective use of nutrition care to improve overall quality of care and wound healing in older adults.

2. Wound Healing and Older Adults

Poorly healing wounds are responsible for pain, increased hospitalization rates, social isolation, longer lengths of hospital stay, limb amputation, and death; risks are often specified by wound type [16]. A newly recognized aspect of wound care is the importance of maintaining or restoring health-related quality of life [17-20]. Conditions such as nutrition, financial burden, socioeconomic and educational status, and acute and chronic stress are variables known to impact both wound healing and patients' quality of life [21]. Similarly, ethnic-based social disparities have been reported to contribute to poor wound healing and lower quality of life [20, 22].

Successful wound healing is a complex process that can be influenced by many factors, including a patient's age, underlying health or disease, nutrition status, and socio-demographic status, along with the wound's size, severity, presence or absence of infection, and location and the blood flow to the wounded area (Figure 1). In older people, poor wound healing is a particular challenge because wounds heal less efficiently with age-related skin changes and with physiological changes related to metabolic diseases and cardiovascular conditions [23, 24]. Complete wound healing is especially challenging in individuals with comorbidities such as obesity or cardiovascular disease [25, 26]. Poor nutrition status, which includes deficiencies in macro- and micronutrients, is a common contributor to impaired wound healing in older adults [27]. The disproportionately high prevalence of poor nutrition in older people may be due to social strains and economic difficulties, in addition to early satiety and other medical problems [28]. As well, some medications commonly used in treating older adults' health conditions can affect skin integrity and impair wound healing, e.g., antibiotics, angiogenesis inhibitors, steroids, and nonsteroidal anti-inflammatory drugs [29, 30]. Irrespective of a patient's age, other wound factors influence the time needed for healing, specifically, the type, size, and severity of a wound, and inflammation, infection, or ischemia [25, 31, 32]. With all these factors interacting, the duration of the wound-healing process varies widely; healing may follow a normal and timely path to resolution, may be interrupted or delayed resulting in a *hard-to-heal* wound, or may be so impaired that the wound is *non-healing* unless specialized treatment strategies and interventions are used.

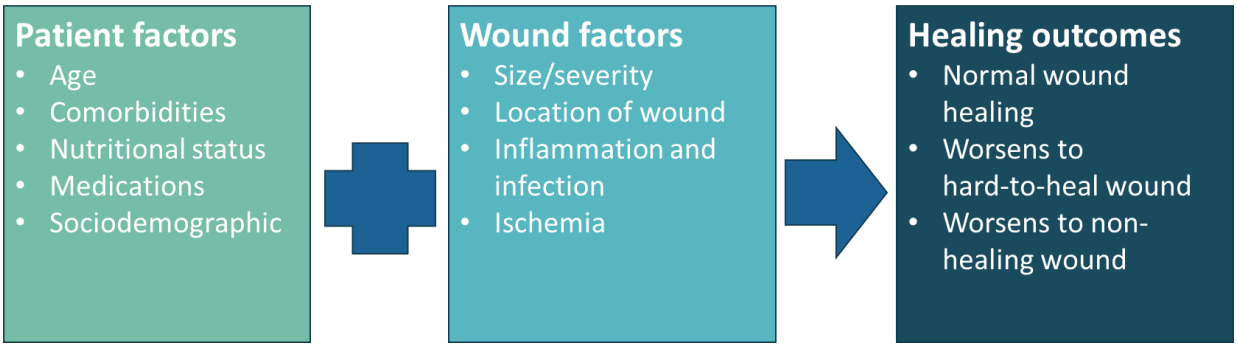

Figure 1 Wound healing factors and outcomes.

All wounds start out as acute wounds. An *acute wound* can result from any traumatic incident that damages the skin, e.g., an abrasion or laceration, a burn, a penetrating or blunt trauma, or a surgical incision [14]. Ideally, an acute wound heals in a timely and orderly manner. A small-sized cut will normally heal within a week by progressing through stages that begin with hemostasis, followed by a precise choreography of cell proliferation, inflammation, innervation, and angiogenesis [14]. By contrast, a larger or hard-to-heal wound follows this same course but can take many months to achieve full wound healing or may develop into a chronic wound [33, 34]. Hard-to-heal and chronic wounds require specialty wound care, which includes multi-disciplinary care for wound management, ongoing wound screening and assessment, and tailored interventions ideally involving nutrition care. Diabetic foot ulcers, venous leg ulcers, and pressure ulcers are examples of chronic lower extremity wounds that are common in older people [35]. In the most severe cases, wounds may fail to heal and therefore become a *non-healing wound.* Wound healing involves a complex interplay between different types of cells, cytokines, mediators, and the vascular system.

In normal healing, the cascade through three healing phases is systematic and efficient. The three phases of wound healing are (i) inflammation, which includes vasoconstriction of blood vessels and platelet aggregation to help stop bleeding, (ii) proliferation of cells to repair tissue and skin damage and prepare for the next phase, and (iii) remodeling, which completes tissue restoration and re-establishes skin integrity [33-37]. These wound-healing processes typically drive the body into a metabolic state that increases energy and protein demand and utilization [14].

3. Nutrition Interventions for Healing Acute and Chronic Wounds

3.1 Macronutrients

To meet increased nutrition demands for healing wounds, sufficient supplies of macronutrients—carbohydrates, proteins, and fats—are critical to restoration of tissue and skin integrity [38]. An appropriate supply of nutrients is also essential to support skin remodeling and reduce scar formation, an important aesthetic outcome [38]. Dietary carbohydrates and proteins can break down into glucose, which is the main metabolic fuel for anabolic processes, including collagen synthesis, fibroblast growth and function, and thus supporting wound healing [39]. Dietary protein is critical for collagen synthesis, tissue remodeling, skin structure, angiogenesis, and fibroblast proliferation [14, 28]. The formation and function of key components of the immune system—leukocytes, monocytes, lymphocytes, and macrophages depend on adequate supplies of protein as well [28]. Without adequate protein supplies, the inflammatory phase of healing may be prolonged with resultant poor healing and even wound dehiscence [14]. In addition, macronutrient fats provide energy for cellular proliferation and are an essential structural component of cell membranes as phospholipids [14]. Fats also play a necessary role in the inflammatory responses important to wound healing; omega-3 and omega-6 fatty acids are precursors to inflammatory-phase mediators, i.e., prostaglandins, leukotrienes, and thromboxane [40].

Along with carbohydrates, protein, and fat, fluid is a fundamental component of wound healing. Fluid helps maintain skin turgor, perfusion, and oxygenation and acts as a dilutant for glucose, micronutrients, and waste removal [28, 41]. Evidence-based recommendations for carbohydrate, protein, fat, and fluid requirements for optimal wound healing are listed in Table 1.

Table 1 Macronutrient and Fluid Requirements for Adults with Wounds.

Nutrient	Role in wound healing	Dietary recommendations
Energy (carbohydrates and fat)	Provision of energy [14]	30-35 kcal/kg body weight/day, or up to 40 kcal/kg body weight/day dependent on baseline body weight, age, comorbidities, activity, stage of wound healing, wound size, and number [28, 40]
Protein	Tissue repair and support [14]	0.8 g/kg body weight/day (healthy adults) [40] 1.0-1.2 g/kg body weight/day (older healthy adults) [42] 1.2-1.5 g/kg body weight/day (older adults with acute or chronic disease), up to 2.0 g/kg body weight/day with severe illness/malnutrition [42] 1.25-2.0 g/kg body weight/day, (pressure injuries) [40]
Water	Support cell function, tissue integrity and perfusion [14]	30 mL/kg body weight/day or 1 to 1.5 mL per calorie consumed [14]

3.1.1 Amino Acids, Branched Chain Amino Acids, and the Leucine Metabolite ß-Hydroxy-ß-Methylbutyrate (HMB)

Wounds are complex and may benefit not just from adequate protein but also from protein components, i.e., specialized amino acids recognized to promote optimal healing. Conditionally essential amino acids are those that cannot be synthesized in sufficient quantities during certain physiological periods, such as during growth or recovery from trauma [43]. For example, the amino acids arginine and histidine, are conditionally essential and may be needed by patients with wounds due to these amino acids' roles in growth and healing processes [28, 44, 45]. Glutamine can be considered conditionally essential too, especially for immune function in stress conditions [46].

Arginine supports cellular proliferation, collagen deposition, and lymphocyte function and serves as a precursor for nitric oxide [13, 40]. Nitric oxide metabolites have been shown to positively affect wound repair [40]. In addition, arginine is an essential component of collagen synthesis and stimulates growth hormone and T cells and positive nitrogen balance [13, 40, 47]. The recommendation for supplementing arginine in patients with pressure or stasis wounds is 4.5 g/day in addition to optimal protein intake [28].

Glutamine is a primary energy source for rapidly multiplying epithelial cells and fibroblasts [40]. Glutamine also plays a role in leukocyte apoptosis, superoxide production, antigen processing, and phagocytosis, which impacts the inflammatory phase of wound healing [28]. Glutamine is critical for tissue repair, cell proliferation, and collagen synthesis [47]. Glutamine supplementation is considered safe for malnourished patients as part of the nutrition management of underlying protein calorie deficits [28]. However, due to conflicting clinical trial results with combination supplements, there is no conclusive evidence to support glutamine supplementation specifically for wound healing [14, 40].

Branched-chain amino acids—valine, leucine, and isoleucine—are essential amino acids that promote protein anabolism and reduce the severity of cachexia, prevent (or treat) hepatic

encephalopathy, promote wound healing, and stimulate insulin production [48]. In addition, leucine also functions as a signaling molecule to stimulate protein synthesis [49].

HMB is a metabolite of leucine and has been shown to both stimulate protein synthesis and decrease protein degradation [49, 50]. Based on the anti-catabolic effects of HMB on muscle mass in healthy adults, including older adults, HMB supplementation has also been studied in other muscle-wasting conditions (e.g., chronic pulmonary disease, hip fracture, and in AIDS-related and cancer-related cachexia) [49]. A review of relevant clinical studies documents that HMB can attenuate the development of sarcopenia in older adults and the effect of HMB was optimal when combined with exercise [49]. A meta-analysis determined that HMB supplementation could mitigate losses of lean body mass in older adults without a significant increase in fat mass [51].

Based on studies demonstrating the efficacy of HMB for maintaining lean body mass, including through stimulating protein synthesis pathways and decreasing protein degradation, more recent research has focused on identifying the efficacy of HMB, arginine, and glutamine to improve wound healing [49]. One study in individuals with diabetes and foot ulcers demonstrated that the use of HMB, arginine, and glutamine improved wound healing but only in patients with poor limb perfusion and/or low serum albumin levels [47]. A more recent retrospective study used electronic health records to compare outcomes of patients with existing wounds in a rehabilitation institution who were given a daily nutrition supplement containing HMB, arginine and glutamine (in addition to usual care) with outcomes of patients receiving usual care only [50]. Patients receiving the nutrition supplement had significant wound healing within 2 weeks of initiation and at twice the rate of healing compared to patients who did not receive the nutrition supplement [50]. Indeed, the use of this wound-specific supplement combined with a hospital diet resulted in a nearly two-fold better wound area reduction compared to the control group [50]. Based on such results, the use of a wound-specific supplement has been included in the European Society for Clinical Nutrition and Metabolism (ESPEN) Guidelines as a promising area of exploration [52].

3.2 Vitamins and Minerals

While the data supporting vitamin and mineral supplementation to enhance wound healing are limited, it is important to ensure that patients are adequately assessed and treated for underlying vitamin and mineral deficiencies that could impact wound healing and lead to poor- or non-healing conditions [40]. Antioxidant vitamins A, C, and E may counteract adverse effects of reactive oxygen species in wounded tissues, and they also contribute to other wound healing processes such as epithelialization (vitamin A), and collagen synthesis and angiogenesis (vitamin C), [53]. A recent study of orthopedic trauma patients documented a high prevalence of vitamin A, C, D, and zinc deficiencies in over half of the study group [54]. Furthermore, low pre-albumin levels and vitamin C deficiency were associated with wound complications in this study [54]. A summary of important vitamins and minerals for optimal wound healing is provided in Table 2.

Table 2 Vitamins and Minerals Important for Wound Healing.

Vitamin/Mineral	Role in wound healing	Dietary Recommendations for wound healing	Clinical benefit from supplementation
Vitamins B- complex	Promote proliferation of skin fibroblasts and keratinocytes; maintain healthy skin and muscle tone; support metabolism, immune, and nervous systems [14, 55]	No wound-specific recommendations	Vitamin combinations: B_9 and B_{12}; B_3, B_5, B_6, and B_{10}; and B_3, B_5, and B_7 vitamin combinations improved wound closure rates by 25-30% [55]
Vitamin A	Stimulates fibroblasts, activates retinoid receptors, and has anti-inflammatory effects Enhances cytokine release in inflammatory phase [40] Enhances production of extracellular matrix components [56]	10,000-25,000IU daily [40, 56]	Preoperative use of Vitamin A in immunodeficient patients or those treated with corticosteroids appears to alleviate anti-wound healing effects of steroids and other immune-suppressive drugs [56]
Vitamin C	Promotes collagen formation, immunomodulation, and antioxidant capacity [40, 57]	500 mg (chronic wounds)- 2 grams (severe wounds) daily [40, 57]	High dose Vitamin C supports the healing of surgical wounds in healthy patients and hard to heal pressure injuries [57, 58].
Vitamin D	Impact on the inflammatory and immune response, proliferation and differentiation of fibroblasts and keratinocytes, and calcium metabolism and signaling [59]	50,000 IU once every two weeks for 12 weeks in patients with diabetic foot ulcers resulted in wound healing vs. placebo [14]	Vitamin D deficiency along with a decrease in calcium signaling can lead to delayed healing or chronic wounds [59].
Vitamin E	Neutralizes oxygen free radicals to prevent tissue damage [14]		The use of supplemental Vitamin E is controversial due to conflicting clinical results [14]
Zinc	Regulation of enzymes involved in tissue repair, growth, and immune function; antioxidant; role in collagen, DNA, RNA and protein synthesis, and cellular proliferation [40]	No supplementation in the absence of deficiency [39, 40]	Zinc deficiency has been reported in patients with chronic wounds [14]; large doses of supplemental zinc over an extended time can induce copper deficiency [60]

		With deficiency: 11 mg/d for men; 8 mg/day for women [39]	
Copper	Engaged in all wound healing stages via cytokine and growth factor modulation [38]		Low copper dietary intake can be increased with supplementation via an oral nutrition supplement [38]
Magnesium	Reduces serum C-reactive protein levels and increases plasma total antioxidant concentration [38]		Magnesium supplementation has been shown to reduce diabetic food ulcer size [61]
Calcium	Regulates cell proliferation and supports hemostasis [14]. Also functions as an extracellular signaling molecule and intracellular messenger for keratinocytes and fibroblasts [62]	No wound-specific dietary recommendations	

3.3 Specialized Nutrition Supplements

Key nutrient supplementation is critical to achieve optimal wound healing in both acute and chronic wounds. Daher et al conducted a systematic review of 28 studies on nutrient supplementation for wound healing in healthy patients and in those with diabetic foot ulcers, pressure injuries, and other wound types [63]. Nutrient supplementation differed across the included studies, and included protein and amino acids, HMB, vitamins and minerals, probiotics, and mixed nutrients [63]. Altogether, findings indicated that arginine and omega-3 supplementation improved wound healing in surgical head and neck cancer, which was demonstrated by a decrease in postoperative complications and reduced length of hospital stay [63]. Vitamin- and mineral-enriched supplements were more effective than non-fortified protein supplements for pressure injuries and diabetic foot ulcers [63]. Formulas containing arginine, omega-3, zinc, vitamins C, D, and E, and magnesium appeared to be the most effective in healing a variety of wounds [63]. Based on the data, wound-specific nutrition supplementation (glutamine, arginine, and omega-3 fatty acids) should be considered for patients with moderate-to-severe injuries, and hard-to-heal wounds to meet their individual nutrient requirements [14]. These key nutrients should be provided at injury onset and during recovery to achieve optimal wound healing. In the case of surgical wounds, these often represent a special case; because surgery is often pre-scheduled, nutrition care can be provided both before (prehabilitation) and after surgery to effectively improve outcomes [64, 65]. A convenient way to provide needed macro- and micronutrients is daily consumption of complete oral nutrition supplements (ONS).

Use of complete ONS or use of complete ONS with enriched protein levels is an effective approach to providing adequate nutrients to support wound healing. Such ONS is best given along with counseling for use and with additional guidance on healthy food intake [14]. For individuals with high risk for nutrition inadequacy, wound-specific nutrition supplements can be added to the treatment regimen, e.g., to provide conditionally essential amino acids such as glutamine, arginine, and HMB, a natural metabolite of leucine. For optimal wound healing, nutrition support should be initiated as soon as possible after injury and tailored to meet the specific needs of the patient and wound type [14].

4. Strategies and Tools for Incorporation of Nutrition Care into Real-World Practice

Professional guidelines specific to nutrition and wound care can provide a basis for developing strategies to improve real-world practice. In addition, given the abundance of evidence for the importance of nutrition to achieve optimal wound healing, updated wound care protocols should specify implementation of nutrition screening, assessment, diagnosis, and intervention [66]. Further, it is important for healthcare systems to implement quality improvement programs to benefit wound care outcomes related to medical and human outcomes as well as healthcare costs and savings.

4.1 Professional Guidelines and Guidance on Nutrition Care and Wound Healing

Nutrition is integral to healing wounds of all types and across clinical settings; as such, good nutrition status is key to achieving optimal wound resolution [13]. Despite this understanding,

Donnelly et al warned that most individuals with diabetic foot ulcers do not meet current consensus recommended levels on optimal dietary intake for wound healing, with many having inadequacies for fiber, zinc, protein, vitamin E, and vitamin A [67]. General guidance on nutrition for wound healing can be sourced from reviews and overviews including:

- Perioperative and enhanced recovery after surgery (ERAS) guideline protocols [64, 68, 69].
- American College of Surgeons preoperative guidelines for older adults [7].
- National Pressure Injury Advisory Panel (NPIAP) guidelines [70] Updated version [71] Development of a fourth edition of the Guidelines (2025) is currently underway.
- Management of diabetic foot ulcers [47, 72].
- Pressure ulcer prevention and healing [73].

Optimizing nutrition as part of quality wound care involves a team of healthcare professionals—ideally at the local level—trained to address associated physiologic and immunologic processes, as well as manage underlying social and societal factors [28]. Members of the team may include clinicians for wound assessment and management, wound care nurses, patient educators, home health caregivers, rehabilitation professionals, mental health specialists, social workers, as well as registered dietitian nutritionists. These team members support the important components of nutrition care and quality improvement.

4.2 Nutrition Screening and Assessment for Diagnosis and Intervention

Determining a wound's cause and characterizing its exact location, size, and severity are essential to providing appropriate care [74]. So too is determining nutrition risk factors and then referral to a nutrition specialist to guide nutrition care. Any screening tool must be quick and easy to administer, reliable, and economical for clinical use. Multiple nutrition screening tools are available, so healthcare professionals can select a tool suitable for the population being screened and the wound care setting [66]. Assessment tools help healthcare professionals make a diagnosis. Once a wound patient is diagnosed as malnourished or at-risk, the next step is referral to a registered dietitian/nutrition professional who develops a nutrition care plan for intervention, and continues with regular follow-up monitoring [75, 76].

4.3 Implementing a Nutrition-Focused Quality Improvement Program (QIP)

One of the ways to advance implementation of nutrition and wound care protocols and interventions is through a nutrition-focused QIP. As identified in a commentary on quality improvement for pressure injuries, "the success of any quality improvement project begins with acknowledging problems, defining and addressing each issue in detail, and setting goals" [77]. In healthcare, quality improvement seeks to standardize care processes for reduced variation, achieve predictable results, improve outcomes for patients and healthcare systems and help meet quality measures. QIP methods can be applied to nutrition and clinical practice [78-81]. Nutrition care models are available for QIP [81, 82], as are exemplary studies related to nutrition in wound healing [79, 80, 83, 84].

Nutrition-focused QIPs are also important for improving outcomes and reducing costs to benefit value-based healthcare. The US Centers for Medicare & Medicaid Services (CMS) has a number of wound care quality measures and related patient safety indicators across multiple US care settings (acute, post-acute, home care, clinic-based care, and private practiced-based care, Supplementary

Table S1 and Supplementary Table S2) [24, 85, 86]. Most recently CMS adopted a new pressure injury electronic clinical quality measure for hospital reporting beginning in 2025 [86]. Leveraging quality nutrition care to improve wound outcomes can have meaningful impact on such quality measures. Nutrition-focused QIPs can also support improved public health, such as the measurable public health objectives for pressure injury readmissions set by the US Office of Disease Prevention and Health Promotion [87].

5. Summary and Conclusions: Nutrition Is Vital for Healing Wounds

Wound healing is a complex process that depends on many factors including a patient's age and underlying health or disease, along with the wound size, severity, and location and the blood flow to the wounded area. A patient's nutrition status plays a prominent role in healing because the catabolic process of inflammation and the anabolic process of wound repair increase nutrition needs. To support wound healing, patients require adequate macro- and micronutrients. In generally healthy and well-nourished individuals, an acute wound will likely follow an efficient and highly predictable pathway to healing. However, with nutrition deficiencies and increased nutrition needs, healing of wounds such as surgical incisions, traumatic injuries, burns, and pressure injuries or diabetic foot ulcers, may be delayed or stopped. Such wounds persist as hard-to-heal chronic wounds or non-healing wounds.

In these more complex cases, nutrition care becomes a critical aspect of overall treatment. For individuals with wounds and nutrition risk or malnutrition, ONS are often recommended to ensure complete and balanced dietary intake, especially adequate protein. In addition, wound-specific nutrition supplements can be added to the treatment regimen, (e.g., to provide amino acids such as glutamine, arginine, leucine and the metabolite of leucine, HMB).

To meet the growing challenge of healing wounds, healthcare professionals across care settings need to implement comprehensive and holistic wound-care strategies to benefit patient and healthcare system outcomes. In addition, today's practitioners must meet wound-related quality measures specific to their site of care, while also aiming to reduce costs for care. Nutrition is a critical intervention for both goals.

Acknowledgements

The authors thank Cecilia Hofmann, Ph.D. (C Hofmann & Associates, Western Springs, IL, USA) for her skillful writing assistance.

Author Contributions

Mary Beth Arensberg: Conceptualization, writing – original draft, writing – review & editing. Bethan E. Phillips: Writing – review & editing. Kirk W. Kerr: Conceptualization, writing – review & editing.

Competing Interests

Kirk W. Kerr and Mary Beth Arensberg are employees and stockholders of Abbott.

Additional Materials

The following additional materials are available in the supplementary materials.

1. Table S1: Examples of Institution-based Wound or Pressure Injury-Related Quality Measures, including those Leveraged by the Centers for Medicare and Medicaid Services (CMS) for Value-based Healthcare.
2. Table S2: Examples of Clinician-based Wound or Pressure Injury-Related Quality Measures, including those Leveraged by the Centers for Medicare and Medicaid Services (CMS) for Value-based Healthcare.

References

1. Brocke T, Barr J. The history of wound healing. Surg Clin. 2020; 100: 787-806.
2. Martinengo L, Olsson M, Bajpai R, Soljak M, Upton Z, Schmidtchen A, et al. Prevalence of chronic wounds in the general population: Systematic review and meta-analysis of observational studies. Ann Epidemiol. 2019; 29: 8-15.
3. WHO. UN decade of healthy ageing 2020-2030 [Internet]. Geneva, Switzerland: WHO; 2020. Available from: https://www.who.int/docs/default-source/decade-of-healthy-ageing/final-decade-proposal/decade-proposal-final-apr2020-en.pdf.
4. Torres MJ, Pedrono G, Rigou A, Carcaillon-Bentata L, Beltzer N. Identifying profiles of people aged 65 and over who fall at home and associated falling-induced injuries: The French ChuPADom study. Injury. 2022; 53: 2511-2518.
5. Dasari N, Jiang A, Skochdopole A, Chung J, Reece EM, Vorstenbosch J, et al. Updates in diabetic wound healing, inflammation, and scarring. Semin Plast Surg. 2021; 35: 153-158.
6. Sen CK. Human wound and its burden: Updated 2020 compendium of estimates. Adv Wound Care. 2021; 10: 281-292.
7. Mohanty S, Rosenthal RA, Russell MM, Neuman MD, Ko CY, Esnaola NF. Optimal perioperative management of the geriatric patient: A best practices guideline from the American College of Surgeons NSQIP and the American Geriatrics Society. J Am Coll Surg. 2016; 222: 930-947.
8. Thomas Hess C. Checklist for factors affecting wound healing. Adv Skin Wound Care. 2011; 24: 192.
9. Nussbaum SR, Carter MJ, Fife CE, DaVanzo J, Haught R, Nusgart M, et al. An economic evaluation of the impact, cost, and Medicare policy implications of chronic nonhealing wounds. Value Health. 2018; 21: 27-32.
10. Pieper B. Vulnerable populations: Considerations for wound care. Ostomy Wound Manage. 2009; 55: 24-37.
11. Robert Wood Johnson Foundation. Medicaid's role in addressing social determinants of health [Internet]. Princeton, NJ: Robert Wood Johnson Foundation; 2019. Available from: https://www.rwjf.org/en/insights/our-research/2019/02/medicaid-s-role-in-addressing-social-determinants-of-health.html.
12. Swoboda L. Social and environmental sources of disparities in wound care [Internet]. Malvern, PA, USA: Wound Source Learning Network; 2023. Available from: https://www.woundsource.com/blog/social-and-environmental-sources-disparities-in-wound-

care#:~:text=Disparities%20in%20social%20determinants%20of,not%20equitably%20distributed%20across%20populations.
13. Ghaly P, Iliopoulos J, Ahmad M. The role of nutrition in wound healing: An overview. Br J Nurs. 2021; 30: S38-S42.
14. Grada A, Phillips TJ. Nutrition and cutaneous wound healing. Clin Dermatol. 2022; 40: 103-113.
15. Penny H, Flores R, Pennington E, Pedersen A, Tran S. The role of macronutrients and micronutrients in wound healing: A narrative review. J Wound Care. 2022; 31: S14-S22.
16. Freedman BR, Hwang C, Talbot S, Hibler B, Matoori S, Mooney DJ. Breakthrough treatments for accelerated wound healing. Sci Adv. 2023; 9: eade7007.
17. Centers for Disease Control and Prevention. Health-related quality of life (HRQOL) [Internet]. Atlanta, GA, USA: Centers for Disease Control and Prevention; 2018. Available from: https://www.cdc.gov/hrqol/concept.htm.
18. Chan DY, Surendra NK, Ng YZ, Lee SH, Yong E, Hong Q, et al. Prospective study on the clinical and economic burden of venous leg ulcers in the tropics. J Vasc Surg Venous Lymphatic Disord. 2023; 11: 954-963.
19. Olsson M, Jarbrink K, Divakar U, Bajpai R, Upton Z, Schmidtchen A, et al. The humanistic and economic burden of chronic wounds: A systematic review. Wound Repair Regen. 2019; 27: 114-125.
20. Zhu X, Olsson MM, Bajpai R, Jarbrink K, Tang WE, Car J. Health-related quality of life and chronic wound characteristics among patients with chronic wounds treated in primary care: A cross-sectional study in Singapore. Int Wound J. 2022; 19: 1121-1132.
21. Fayne RA, Borda LJ, Egger AN, Tomic-Canic M. The potential impact of social genomics on wound healing. Adv Wound Care. 2020; 9: 325-331.
22. Goh OQ, Ganesan G, Graves N, Ng YZ, Harding K, Tan KB. Incidence of chronic wounds in Singapore, a multiethnic Asian country, between 2000 and 2017: A retrospective cohort study using a nationwide claims database. BMJ Open. 2020; 10: e039411.
23. Bonifant H, Holloway S. A review of the effects of ageing on skin integrity and wound healing. Br J Community Nurs. 2019; 24: S28-S33.
24. International Council on Active Aging. Taking the next step forward [Internet]. Vancouver, BC, Canada: International Council on Active Aging; 2022. Available from: https://www.icaa.cc/data/product/8913_e7f556cb7ca6f20f6e46977ae7e3a76c.pdf.
25. Pierpont YN, Dinh TP, Salas RE, Johnson EL, Wright TG, Robson MC, et al. Obesity and surgical wound healing: A current review. ISRN Obes. 2014; 2014: 638936.
26. Guo S, Dipietro LA. Factors affecting wound healing. J Dent Res. 2010; 89: 219-229.
27. Norman K, Hass U, Pirlich M. Malnutrition in older adults-recent advances and remaining challenges. Nutrients. 2021; 13: 2764.
28. Quain AM, Khardori NM. Nutrition in wound care management: A comprehensive overview. Wounds. 2015; 27: 327-335.
29. Beitz JM. Pharmacologic impact (aka "Breaking Bad") of medications on wound healing and wound development: A literature-based overview. Ostomy Wound Manage. 2017; 63: 18-35.
30. Khalil H, Cullen M, Chambers H, McGrail M. Medications affecting healing: An evidence-based analysis. Int Wound J. 2017; 14: 1340-1345.
31. Li WW, Carter MJ, Mashiach E, Guthrie SD. Vascular assessment of wound healing: A clinical review. Int Wound J. 2017; 14: 460-469.

32. Browder SE, Ngeve SM, Hamrick ME, Wood JE, Parodi FE, Pascarella LE, et al. Analysis of wound healing time and wound-free period in patients with chronic limb-threatening ischemia treated with and without revascularization. J Vasc Surg. 2022; 76: 1667-1673.e1.
33. Canedo-Dorantes L, Canedo-Ayala M. Skin acute wound healing: A comprehensive review. Int J Inflamm. 2019; 2019: 3706315.
34. Gurtner GC, Werner S, Barrandon Y, Longaker MT. Wound repair and regeneration. Nature. 2008; 453: 314-321.
35. Frykberg RG, Banks J. Challenges in the treatment of chronic wounds. Adv Wound Care. 2015; 4: 560-582.
36. Ozgok Kangal MK, Regan JP. Wound healing. In: StatPearls [Internet]. Treasure Island, FL: StatPearls Publishing; 2023.
37. Wallace HA, Basehore BM, Zito PM. Wound healing phases. In: StatPearls [Internet]. Treasure Island, FL: StatPearls Publishing; 2023.
38. Seth I, Lim B, Cevik J, Gracias D, Chua M, Kenney PS, et al. Impact of nutrition on skin wound healing and aesthetic outcomes: A comprehensive narrative review. JPRAS Open. 2024; 39: 291-302.
39. Stechmiller JK. Understanding the role of nutrition and wound healing. Nutr Clin Pract. 2010; 25: 61-68.
40. Shields BE. Diet in wound care: Can nutrition impact healing? Cutis. 2021; 108: 325-328.
41. Ousey K, Cutting KF, Rogers AA, Rippon MG. The importance of hydration in wound healing: Reinvigorating the clinical perspective. J Wound Care. 2016; 25: 122-130.
42. Bauer J, Biolo G, Cederholm T, Cesari M, Cruz-Jentoft AJ, Morley JE, et al. Evidence-based recommendations for optimal dietary protein intake in older people: A position paper from the PROT-AGE Study Group. J Am Med Dir Assoc. 2013; 14: 542-559.
43. Lopez M, Mohiuddin S. Biochemistry essential amino acids. In: StatPearls [Internet]. Treasure Island, FL: StatPearls Publishing; 2024.
44. Hendrickson NR, Davison J, Glass NA, Wilson ES, Miller A, Leary S, et al. Conditionally essential amino acid supplementation reduces postoperative complications and muscle wasting after fracture fixation: A randomized controlled trial. J Bone Joint Surg Am. 2022; 104: 759-766.
45. Lorenz KJ, Schallert R, Daniel V. Immunonutrition-The influence of early postoperative glutamine supplementation in enteral/parenteral nutrition on immune response, wound healing and length of hospital stay in multiple trauma patients and patients after extensive surgery. GMS Interdiscip Plast Reconstr Surg DGPW. 2015; 4: Doc15.
46. Cruzat V, Macedo Rogero M, Noel Keane K, Curi R, Newsholme P. Glutamine: Metabolism and immune function, supplementation and clinical translation. Nutrients. 2018; 10: 1564.
47. Armstrong DG, Hanft JR, Driver VR, Smith AP, Lazaro-Martinez JL, Reyzelman AM, et al. Effect of oral nutritional supplementation on wound healing in diabetic foot ulcers: A prospective randomized controlled trial. Diabet Med. 2014; 31: 1069-1077.
48. Holecek M. Branched-chain amino acids in health and disease: Metabolism, alterations in blood plasma, and as supplements. Nutr Metab. 2018; 15: 33.
49. Holecek M. Beta-hydroxy-beta-methylbutyrate supplementation and skeletal muscle in healthy and muscle-wasting conditions. J Cachexia Sarcopenia Muscle. 2017; 8: 529-541.

50. Clark RK, Stampas A, Kerr KW, Nelson JL, Sulo S, Leon-Novelo L, et al. Evaluating the impact of using a wound-specific oral nutritional supplement to support wound healing in a rehabilitation setting. Int Wound J. 2023; 20: 145-154.
51. Wu H, Xia Y, Jiang J, Du H, Guo X, Liu X, et al. Effect of beta-hydroxy-beta-methylbutyrate supplementation on muscle loss in older adults: A systematic review and meta-analysis. Arch Gerontol Geriatr. 2015; 61: 168-175.
52. Wunderle C, Gomes F, Schuetz P, Stumpf F, Austin P, Ballesteros-Pomar MD, et al. ESPEN guideline on nutritional support for polymorbid medical inpatients. Clin Nutr. 2023; 42: 1545-1568.
53. Barchitta M, Maugeri A, Favara G, Magnano San Lio R, Evola G, Agodi A, et al. Nutrition and wound healing: An overview focusing on the beneficial effects of curcumin. Int J Mol Sci. 2019; 20: 1119.
54. Handcox JE, Gutierrez-Naranjo JM, Salazar LM, Bullock TS, Griffin LP, Zelle BA. Nutrition and vitamin deficiencies are common in orthopaedic trauma patients. J Clin Med. 2021; 10: 5012.
55. Rembe JD, Fromm-Dornieden C, Stuermer EK. Effects of vitamin B complex and vitamin C on human skin cells: Is the perceived effect measurable? Adv Skin Wound Care. 2018; 31: 225-233.
56. Polcz ME, Barbul A. The role of Vitamin A in wound healing. Nutr Clin Pract. 2019; 34: 695-700.
57. Palmieri B, Vadala M, Laurino C. Nutrition in wound healing: Investigation of the molecular mechanisms, a narrative review. J Wound Care. 2019; 28: 683-693.
58. Bechara N, Flood VM, Gunton JE. A systematic review on the role of Vitamin C in tissue healing. Antioxidants. 2022; 11: 1605.
59. Bikle DD. Role of vitamin D and calcium signaling in epidermal wound healing. J Endocrinol Investig. 2023; 46: 205-212.
60. Plum LM, Rink L, Haase H. The essential toxin: Impact of zinc on human health. Int J Environ Res Public Health. 2010; 7: 1342-1365.
61. Razzaghi R, Pidar F, Momen-Heravi M, Bahmani F, Akbari H, Asemi Z. Magnesium supplementation and the effects on wound healing and metabolic status in patients with diabetic foot ulcer: A randomized, double-blind, placebo-controlled trial. Biol Trace Elem Res. 2018; 181: 207-215.
62. Subramaniam T, Fauzi MB, Lokanathan Y, Law JX. The role of calcium in wound healing. Int J Mol Sci. 2021; 22: 6486.
63. Daher GS, Choi KY, Wells JW, Goyal N. A systematic review of oral nutritional supplement and wound healing. Ann Otol Rhinol Laryngol. 2022; 131: 1358-1368.
64. Ljungqvist O, de Boer HD, Balfour A, Fawcett WJ, Lobo DN, Nelson G, et al. Opportunities and challenges for the next phase of Enhanced Recovery After Surgery: A review. JAMA Surg. 2021; 156: 775-784.
65. Weimann A, Braga M, Carli F, Higashiguchi T, Hubner M, Klek S, et al. ESPEN practical guideline: Clinical nutrition in surgery. Clin Nutr. 2021; 40: 4745-4761.
66. Munoz N, Litchford M, Cereda E. Nutrition and wound care. Phys Med Rehabil Clin. 2022; 33: 811-822.
67. Donnelly HR, Clarke ED, Collins CE, Collins RA, Armstrong DG, Mills JL, et al. Most individuals with diabetes-related foot ulceration do not meet dietary consensus guidelines for wound healing. Int Wound J. 2024; 21: e14483.

68. Brajcich BC, Stigall K, Walsh DS, Varghese TK, Barber AE, Kralovich KA, et al. Preoperative nutritional optimization of the oncology patient: A scoping review. J Am Coll Surg. 2022; 234: 384-394.
69. Mudarra Garcia N, Naranjo Pena I, Olivares Pizarro SP, Riquelme Oliveira A, Granizo Martinez JJ, Rodriguez Prieto I, et al. Pre-surgical nutrition support reduces the incidence of surgical wound complications in oncological patients. Nutr Cancer. 2020; 72: 801-807.
70. National Pressure Ulcer Advisory Panel, European Pressure Ulcer Advisory Panel, Pan Pacific Pressure Injury Alliance. Prevention and treatment of pressure ulcers: Quick reference guide. Osborne Park, Australia: Cambridge Media; 2014.
71. Kottner J, Cuddigan J, Carville K, Balzer K, Berlowitz D, Law S, et al. Prevention and treatment of pressure ulcers/injuries: The protocol for the second update of the international Clinical Practice Guideline 2019. J Tissue Viability. 2019; 28: 51-58.
72. Chen P, Vilorio NC, Dhatariya K, Jeffcoate W, Lobmann R, McIntosh C, et al. Guidelines on interventions to enhance healing of foot ulcers in people with diabetes (IWGDF 2023 update). Diabetes Metab Res Rev. 2023; 40: e3644.
73. Munoz N, Posthauer ME, Cereda E, Schols J, Haesler E. The role of nutrition for pressure injury prevention and healing: The 2019 International Clinical Practice Guideline Recommendations. Adv Skin Wound Care. 2020; 33: 123-136.
74. Nagle SM, Stevens KA, Wilbraham SC. Wound assessment. In: StatPearls [Internet]. Treasure Island, FL: StatPearls Publishing; 2023.
75. Swan WI, Pertel DG, Hotson B, Lloyd L, Orrevall Y, Trostler N, et al. Nutrition Care Process (NCP) Update Part 2: Developing and using the NCP terminology to demonstrate efficacy of nutrition care and related outcomes. J Acad Nutr Diet. 2019; 119: 840-855.
76. Swan WI, Vivanti A, Hakel-Smith NA, Hotson B, Orrevall Y, Trostler N, et al. Nutrition Care Process and model update: Toward realizing people-centered care and outcomes management. J Acad Nutr Diet. 2017; 117: 2003-2014.
77. Kennepp L. 2023 Resolutions: It's time to revamp your pressure injury prevention programs. Healthc Manage Forum. 2023; 36: 5-14.
78. Arensberg MB, Richards J, Benjamin J, Kerr K, Hegazi R. Opportunities for Quality Improvement Programs (QIPs) in the nutrition support of patients with cancer. Healthcare. 2020; 8: 227.
79. Fitall E, Pratt KJ, McCauley SM, Astrauskas G, Heck T, Hernandez B, et al. Improving malnutrition in hospitalized older adults: The development, optimization, and use of a supportive toolkit. J Acad Nutr Diet. 2019; 119: S25-S31.
80. Hwang JM. Time is tissue. Want to save millions in wound care? Start early: A QI project to expedite referral of high-risk wound care patients to specialised care. BMJ Open Qual. 2023; 12: e002206.
81. Malnutrition Quality Improvement Initiative (MQii). Global malnutrition composite score [Internet]. New York: Malnutrition Quality Improvement Initiative; 2023. Available from: https://malnutritionquality.org/gmcs-for-iqr/.
82. Arensberg MB, Brunton C, Richardson B, Bolhack S. The case for malnutrition quality measures and nutrition-focused Quality Improvement Programs (QIPs) in US skilled nursing facilities. Healthcare. 2022; 10: 549.
83. Citty SW, Cowan LJ, Wingfield Z, Stechmiller J. Optimizing nutrition care for pressure injuries in hospitalized patients. Adv Wound Care. 2019; 8: 309-322.

84. Pratt KJ, Hernandez B, Blancato R, Blankenship J, Mitchell K. Impact of an interdisciplinary malnutrition quality improvement project at a large metropolitan hospital. BMJ Open Qual. 2020; 9: e000735.
85. US Wound Registry US Podiatry Registry. Measure the right thing: Quality measures [Internet]. The Woodlands, TX, USA: US Wound Registry US Podiatry Registry; 2023 Available from: https://uswoundregistry.com/quality-measures/.
86. Centers for Medicare & Medicaid Services. FY 2024 Hospital Inpatient Prospective Payment System (IPPS) and Long-Term Care Hospital Prospective Payment System (LTCH PPS) Final rule — CMS-1785-F and CMS-1788-F fact sheet [Internet]. Baltimore, MD, USA: Centers for Medicare & Medicaid Services; 2023. Available from: https://www.cms.gov/newsroom/fact-sheets/fy-2024-hospital-inpatient-prospective-payment-system-ipps-and-long-term-care-hospital-prospective-0.
87. Healthy People 2030. Reduce the rate of pressure ulcer-related hospital admissions among older adults — OA-04 [Internet]. Washington, DC: Office of the Assistant Secretary for Health; 2016. Available from: https://health.gov/healthypeople/objectives-and-data/browse-objectives/older-adults/reduce-rate-pressure-ulcer-related-hospital-admissions-among-older-adults-oa-04.