The role of nutrition in successful wound healing

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Healthy eating is a topic covered widely in the media, and is particularly relevant to healthcare, with diet and nutrition vital to the management and prevention of many conditions. Wound healing is a complex process that relies on the coordination and internal regulation of activities such as the removal of devitalised tissue and growth of fresh blood vessels. This article examines the phases of wound healing and discusses how nutrients can affect and enhance this process. Understanding the role of nutrients in wound care enables nurses to offer advice to patients whose wounds are not progressing in the expected manner. Nutrition should form part of holistic wound assessment, with any malnourished patient being referred to a dietician. It is a misconception that only underweight individuals can be malnourished and the use of a robust assessment tool will assist nurses in deciding which patients require onward referral. There appears to be a significant link between poor nutrition and delayed wound healing, with a higher risk of complications such as infection identified in malnourished patients.

KEYWORDS:
■ Assessment ■ Healing ■ Malnutrition ■ Nutrition ■ Wounds

Nutrition is a basic requirement of the human body, enabling it to function effectively. Providing optimal nutrition has become a major concern in health and social care over the last two decades, with some areas, particularly obesity and sugar intake, becoming a focus of national policies. For example, the Department of Health (DH) released a policy on obesity (DH, 2015), and the British Nutrition Foundation (2015) and British Heart Foundation (BHF) (2015) released healthy eating guidance. At the same time, the NHS released practical healthy eating campaigns aimed at patients, such as *Live Well; Healthy Eating* (NHS, 2015a), and *Change4Life* (NHS, 2015b).

Nutritional factors can affect many health conditions such as diabetes and heart failure, and optimal nutrition aids the maintenance of overall health. Despite this, healthcare professionals do not always appreciate the link between nutrition and wound healing and the patient's diet is often not considered until their wound becomes infected or fails to heal in a timely manner.

Guidance suggests that a nutritious diet aimed at promoting wound healing should ideally encompass hydration; nutrients including proteins and amino acids; vitamin A, vitamin B complex, vitamin C and vitamin E; iron, zinc and copper; and fats and carbohydrates (NHS, 2015a). Nurses should be aware of the components of different food types if they are to provide appropriate nutritional advice to patients.

Wound healing can become delayed in patients who experience periods of starvation, or who are undernourished (Todorovic, 2002; Wild et al, 2010). Malnutrition can be defined as an imbalance between nutritional requirements and intake, causing the body to experience measurable adverse effects (British Association of Parenteral and Enteral Nutrition (BAPEN), 2017). Malnutrition was outlined as a significant problem in hospitals by Edington et al (2000) and chronic illnesses, such as chronic obstructive pulmonary disorder (COPD) and rheumatoid arthritis, which are often present in patients with chronic wounds, can lead to protein energy malnutrition.

NORMAL WOUND HEALING

Wound healing is a process that relies on the coordination and internal regulation of various activities in such a way that healing progresses in a timely manner and 100% epithelialisation occurs. Wound healing usually takes place in three overlapping phases; inflammation (with initial haemostasis), proliferation, and epithelialisation and remodelling (Clark, 1996).

Inflammation

Following initial injury, haemostasis results in vasoconstriction and the formation of a fibrin clot. Once homeostasis is established, vasodilation occurs and the increased blood flow leads to migration of neutrophils, macrophages and enzymes to the wound site. This is known as the inflammatory phase,

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during which neutrophils and macrophages are vital. They digest bacteria and autolyse devitalised tissue. Wounds will discharge exudate during this process and there may be decreased function in the area affected, for example, restricted movement to the area/limb due to localised swelling. If there is no infection present, or any other barrier to healing, such as ischaemia, the inflammatory cell numbers reduce and the next phase of wound healing commences (Schulz, 2000).

Proliferation

Proliferation is the second stage of the wound-healing trajectory and during this stage fibroblast cell numbers increase, helping to repair tissue and build the foundations to create the base of the wound with new granulation tissue (Timmons, 2006). During this stage, the wound starts to rebuild itself. New capillaries are formed and an extracellular matrix is produced. This stage should last around 5-24 days and is characterised by the presence of macrophages and fibroblasts. These stimulate angiogenesis (formation of new blood vessels), which enables the tissues to receive oxygen and nutrients.

Epithelialisation and remodelling

When the wound is filled with healthy granulation tissue, wound contraction takes place and epithelialisation can proceed. Epithelialisation encourages restoration of the skin's integrity. Keratinocytes migrate from the wound edges until the wound is covered (Broderick, 2009) and proteins, including collagen and elastin, are synthesised to form scar tissue.

Remodelling occurs as the wound closes. Sometimes called maturation, the tensile strength of the wound increases during this phase, which can last for several months. It can take up to two years to return the tissue to its pre-injured state (Scholl and Langkamp-Henken, 2001).

Nurses should advise patients to take a balanced diet throughout the wound-healing process and support this with leaflets and websites (British Nutrition Foundation, www.nutrition.or.uk; British Heart Foundation, www.bhf.org.uk). Carbohydrates, proteins, fruit, vegetables and dairy products should all form part of a healthy diet. However, if nurses are to guide patients towards the food groups that will encourage wound healing, they must be aware of the role of different nutrients throughout the healing process.

NUTRIENTS REQUIRED DURING WOUND HEALING

Inflammation

Successful activation of the clotting cascade and formation of the fibrin clot during haemostasis requires calcium and vitamin K. Vitamin K encompasses a group of fat-soluble vitamins obtained from leafy green vegetables, avocado, meat and dairy products. It is required for the modification of some proteins used for coagulation and bone metabolism (Nelsestuen et al, 2000).

Vitamin A is important during the early inflammatory response and is required for the migration of macrophages, monocytes and fibroblasts (Lansdown, 2004; Brown and Phillips, 2010). Vitamin A is fat soluble and is obtained from carotene in vegetables (Brown and Phillips, 2010). However, too much vitamin A is known to cause a variety of metabolic changes in the skin, such as roughness and scaling, as well as weakening the hair (Lansdown, 2004).

Vitamin E is an antioxidant with anti-inflammatory properties (Guo and DiPietro, 2010), and is found in nuts, vegetable oil and seeds. Vitamin E is essential for the stability of cell walls and deficiency can expedite the death of blood cells (Todorovic, 2002).

Protein contains nitrogen, which enables the provision of amino acids. Proteins play a role in the immune system and aid the growth and repair of tissue (Collins, 2001; Wild et al, 2010). It is understood that arginine's (an amino acid) role during the inflammatory phase of healing can influence processes in the phases that follow. While not essential in a healthy individual, the metabolic demand for arginine increases during surgery, trauma and in psychologically stressful circumstances, which often involve a wound (Williams, 2002; Guo and DiPietro, 2010).

Glutamine, the most abundant amino acid in the blood, provides a source of glucose preferred as an energy source by white blood cells and is required for the glutathione antioxidant used in healing (Sherman and Barkley, 2011). While the body can synthesise glutamine under normal circumstances, when demand is increased, as in wound healing, additional glutamine is sought from the diet. Glutamine is crucial for stimulating the inflammatory response (Arnold and Barbul, 2006), and is found in a variety of protein-rich foods, including beef, chicken, fish, dairy products, eggs, celery and wheat. Vegetarians and vegans can increase their protein intake by consuming pulses and, while only containing around 3% protein, Brussel sprouts, parsley and spinach are better sources than other vegetables.

Lipids and essential fatty acids also contribute to inflammatory reactions (Lansdown, 2004), although polyunsaturated and monosaturated fats are preferable as they provide a crucial energy source, by-products protect the cells and polyunsaturates have an anti-inflammatory response (Dobson and Williams, 2003; Demling, 2009). Lipids and essential fatty acids can be sourced from oily fish, nuts, seeds and vegetable oils.

Zinc is a mineral involved in a number of complex processes in wound healing. During the inflammatory phase, it assists in the modulation of the immune response (Demling, 2009), and chronic zinc deficiency increases inflammation (Bonaventura et al, 2015). Following injury, zinc levels in healthy tissue are redistributed to the wounded tissue, contributing to improved immune function (Demling, 2009). Red meat, liver, nuts, milk and cereals all provide zinc.

Diabetes can have a significant effect on wound healing, with poorly

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controlled diabetes being associated with increased susceptibility to infection and necrosis (Lansdown, 2004). Therefore, monitoring blood glucose levels and glycated haemoglobin (HbA1c) can help ensure adequate diabetic control. Educating patients on how their sugar intake can adversely affect this phase of healing is important.

Proliferation

Amino acids are essential for successful progression of this phase of healing. Arginine aids modulation of collagen deposition (Singer, 2002), enhances angiogenesis and has a role in wound contraction (Scholl and Langkamp-Henken, 2001). The amino acids cysteine and proline adversely affect some processes, such as neoangiogenesis (the formation of new blood vessels in tumours) and collagen synthesis (Brown and Phillips, 2010).

Fibroblasts have been observed to have some sensitivity to glucose deficiency, affecting their growth and proliferation (Han et al, 2004).

Vitamin B complex consists of eight water soluble vitamins that are found in a variety of food types including meat, fish, dairy products and cereals. It supports metabolic rate and assists in the promotion of cell proliferation (Brown and Phillips, 2010). Each B vitamin has its own reference nutrient intake (RNI), for example folic acid is 200mcg and B6 is 1.4mcg (Committee on Medical Aspects of Food and Nutrition Policy [COMA], 1991). Some dieticians have suggested providing 200% of the recommended daily amount of vitamin B complex for patients with wounds (Flanigan, 1997).

Lipids and fatty acids provide energy throughout the wound-healing process and for proliferation and act as building blocks for epidermal and dermal tissues (Brown and Phillips, 2010). Lipids and essential fatty acids are involved in cell membrane synthesis and assist in construction of the intracellular matrix (Lansdown, 2004). The essential fatty acids linoleic and alpha-linolenic must be consumed through the patient's diet, as it is not possible to synthesis them (Demling, 2009). They are also used to build other omega fatty acids.

Zinc is involved with cell proliferation and is therefore necessary for proliferation when the wound is rebuilding itself (Todorovic, 2002).

The role of iron in preventing anaemia is well understood. However, iron's role in forming haemoglobin also means that it has a key role in optimising tissue perfusion (Flanigan, 1997), which is important throughout the healing process. It can also assist in collagen synthesis and is sourced from liver, red meat, fortified cereals, pulses and green vegetables. Iron deficiency can lead to impaired collagen cross-linking and reduced wound strength (Todorovic, 2002).

Epithelialisation and remodelling

Collagen remodelling increases the tensile strength of the wound. The wound also devascularises during this phase. Collagen deposition and remodelling is thought to be adversely affected by protein and vitamin C deficiency, increasing the risk of dehiscence in surgical wounds and wound reopening in scurvy (Scholl and Langkamp-Henken, 2001; Sherman and Barkley, 2011). Vitamin C (ascorbic acid) is required in the synthesis of collagen and stabilises the triple helix structure of collagen (Wild et al, 2010). Vitamin C can be obtained in the diet from citrus fruits and green vegetables, as well as potatoes.

The amino acids cysteine and proline adversely affect some wound-healing processes, such as collagen synthesis (Brown and Phillips, 2010). Conversely, arginine, already mentioned as essential during inflammation and proliferation, can aid the regulation of collagen deposition (Singer, 2002; Wild et al, 2010). Glutamine supplements have been shown to improve wound strength and increase levels of mature collagen (da Costa et al, 2003).

Vitamin E is used in many skin moisturiser products and is believed to have a role in reducing scar formation with topical application (Guo and DiPietro, 2010), although this is debated in the literature (Khoosal and Goldman, 2006).

The mineral zinc is a cofactor in collagen synthesis and has a role in the maturation of collagen (Flanigan, 1997; Todorovic, 2002; Demling, 2009). Deficiency can lead to a decreased epithelialisation rate and reduced wound strength (Todorovic, 2002).

The importance of water to wound healing is often overlooked. Water provides a structural component in the cytoplasm of skin cells as well as an environmental component, allowing the migration and maturation of epidermal cells (Lansdown 2004).

PATIENT ASSESSMENT AND OPTIMISING NUTRITIONAL STATUS

Overall, the effect of various nutrients on the different phases of wound healing demonstrates the importance of a well-balanced diet. Main meals should consist of 20% protein, 40% vegetables/salad/fruit and 40% carbohydrate (Dobson and Williams, 2003). If such a diet is maintained, the body should have all the nutrients it requires for timely wound healing. However, in the presence of some chronic diseases, such as diabetes and rheumatoid arthritis, following major surgery, or when a person is experiencing increased psychological stress, malnutrition may still be a factor and nurses should not overlook the importance of maintaining energy levels. Energy from fats and carbohydrates are used to provide energy for cell metabolism and caution must be taken when assessing obese patients, as weight loss plans are not usually appropriate when promoting wound healing in this group (Flanigan, 1997).

It is a misconception that only underweight individuals can be malnourished. The imbalance between what is nutritionally required and what is consumed can include people eating too much food, particularly from certain food groups, such as fats and refined carbohydrates, as well as too little.

In addition to the risk of people who are obese lacking essential nutrients through consuming foods that provide little nutritional value for wound healing, other problems include wound dehiscence, infections and compromised circulation due to the low density of blood vessels in fat tissue, which can result in decreased blood flow to the wound (Perkins, 1992; Guo and DiPietro, 2010). There is also evidence that a relationship exists between increased weight and the severity of venous disease (Barber et al, 2017).

Optimal holistic wound assessment should include nutritional assessment. Establishing the phase of wound healing and identifying any abnormalities in the process, such as prolonged inflammation or failure to epithelialise, can help the nurse to identify the nutrients involved, or missing. The nurse can then advise patients to focus on specific areas of their diet. Barber et al (2017) suggested a programme of optimising nutritional status by correcting deficiencies. Proteins and amino acids affect all the phases of wound healing and are understood to have the most important role of all nutrients throughout the healing process (Brown and Phillips, 2010; Wild et al, 2010), although a number of others are also influential in all three phases, such as amino acids and zinc.

The National Institute for Health and Care Excellence (NICE, 2012) recommends that nutritional screening should assess the patient's body mass index (BMI) and percentage of unintentional weight loss, as well as considering the time over which nutrient intake has been reduced and/or the likelihood of impaired nutritional intake in the future. A number of validated tools are available, however, BAPEN (2017) recommend the Malnutrition Universal Screening Tool (MUST).

Anthropometric measurements can be used to assess body composition and also assist in diagnosing nutritional insufficiency (Flanigan, 1997; British Dietetics Association (BDA), 2012). When a number of such measurements are taken, this will provide the nurse with information about the patient's anatomical make up in terms of bone, muscle, water and fat (BDA, 2012).

Patients identified with, or at significant risk of, malnutrition should be seen by a dietician, who can offer more detailed advice about nutritional intake. Blood results are also beneficial. Patients are often considered at high risk of malnutrition when albumin levels fall below 35g/l. However, low levels of albumin may indicate the presence of inflammation or infection and, therefore, this reading alone should not be used to determine nutritional status (BDA, 2012).

Supplements

Supplements may be indicated in some circumstances, although Langer and Fink (2014), and Haughey and Barbul (2017) advised that there was no clear evidence of any benefit of nutritional interventions in patients with pressure ulcers. However, one randomised controlled trial found that the use of a high energy supplement containing arginine, zinc and antioxidants improved healing in malnourished patients with pressure ulcers (Cereda et al, 2015). Although not looking specifically at patients with wounds, Cawood et al (2011) found that the use of high protein supplements led to clinical benefits in a meta-analysis of 36 randomised controlled trials.

Many clinical guidelines, for example, those for venous leg ulcers, consider nutritional supplements but do not advise on the management of obese patients (Barber et al, 2017). General consensus is that a review by a dietician is vital for all malnourished patients and patient with wounds to assess the appropriateness of vitamin and mineral supplements (Dobson and Williams, 2003; Guo and DiPietro, 2010). However, further research is needed to establish which levels of supplements produce the most effective results and under which circumstances.

CONCLUSION

Wound healing is a complex process that can be enhanced by optimising nutrition. There appears to be a strong link between poor nutrition and factors including delayed wound healing and the risk of complications such as infections. During healing, different stages of the wound-healing process progress at different rates and a poor nutritional status can cause delays. Each stage of the wound-healing trajectory requires different nutrients (Todorovic, 2002), and research suggests that a well-balanced nutritious diet will promote wound healing, while supplements may be useful in malnourished individuals.

All patients with wounds should be assessed for risk of or signs of malnutrition. Advice must be given on dietary intake to optimise the healing process. Nurses need to be aware of the components of a balanced diet and which foods are

Practice points

- A nutritious diet should include proteins and amino acids (20%), carbohydrates (40%) and fruit and vegetables (40%) to ensure optimal consumption of vitamins, iron, zinc and fats.
- Calcium, vitamins K, A and E, proteins and amino acids, polyunsaturated and monounsaturated fats, and zinc are important for haemostasis and the inflammatory phase.
- Proteins and amino acids, glucose, vitamin B, lipids and fatty acid, zinc, and iron all provide vital support during proliferation.
- Epithelialisation and remodelling require proteins and amino acids, vitamins C and E, and zinc. Water is also important during this phase.
- Weight loss plans may not be appropriate during wound healing.
- Holistic wound assessment should include nutritional assessment. A validated nutritional screening tool, such as MUST (BAPEN, 2017), is useful.
- Patients with, or at significant risk of malnutrition should be seen by a dietician. Supplements may be indicated.

particularly beneficial at certain stages of healing, especially in circumstances where the wound is not progressing as it should. Patients who are malnourished must be reviewed by a dietician, who can provide more detailed assessment and introduce an appropriate management plan.

Optimising nutritional intake will aid timely wound healing, which, in turn, will reduce healthcare and social costs as well as improving quality of life for the person affected by the wound and their family and/or carers. Further research is required to assess how best to optimise patients' nutrition. However, nurses should ensure that nutritional status forms part of routine assessment of wounds and that advice on the management of a balanced diet, including all the key nutrients, is provided as a minimum. JCN

REFERENCE

Arnold M, Barbul A (2006) Nutrition and wound healing. *Plast Reconstr Surg* 117(Suppl 7): 42S–58S

British Association for Parenteral and Enteral Nutrition (2017) *Introduction to Malnutrition*. Available online: www.bapen.org.uk/malnutrition-undernutrition/introduction-to-malnutrition (accessed 13 April, 2018)

Barber GA, Weller CD, Gibson SJ (2017) Effects and associations of nutrition in patients with venous leg ulcers: a systematic review. *J Adv Nurs* 74(4): 1–14

British Dietetics Association (2012) Model *and Process for Nutrition and Dietetic Practice*. Available online: www.bda.uk.com/publications/professional/model (accessed 13 April, 2018)

British Heart Foundation (2015) *Healthy eating*. Available online: www.bhf.org.uk/heart-health/preventing-heart-disease/healthy-eating (accessed 13 April, 2018)

Bonaventura P, Benedetti G, Albarède F, et al (2015) Zinc and its role in immunity and inflammation. *Autoimmun Rev* 14(4): 277–85

British Nutrition Foundation (2015) *Healthy diet recommendations*. Available online: www.nutrition.org.uk/healthyliving/healthyeating.html (accessed 13 April, 2018)

Broderick BN (2009) Understanding chronic wound healing. *Nurse Pract* 34(10): 16–22

Brown KL, Phillips TJ (2010) Nutrition and wound healing. *Clin Dermatol* 28: 432–9

Cawood AL, Elia M, Stratton RJ (2011) Systematic review and meta-analysis of the effects of high protein oral nutritional supplements. *Ageing Res Rev* 11: 278–96

Cereda E, Klersy C, Serioli M, et al (2015) A nutritional formula enriched with arginine, zinc and antioxidants for the healing of pressure ulcers: a randomized controlled trial. *Ann Int Med* 162(3): 167–74

Clark RAF (1996) Wound repair; overview and general considerations. In: Clark RAF, ed. *The Molecular and Cellular Biology of Wound Repair*. 2nd ed. Plenum Press, London: 3–50

Collins N (2001) Nutrition Q and A, protein and wound healing. *Adv Skin Wound Care* 14(6): 288–9

Committee on Medical Aspects of Food and Nutrition Policy (1991) Dietary reference values for food energy and nutrients for the United Kingdom. *Report of the Panel on Dietary Reference Values of the Committee on Medical Aspects of Food Policy* 41: 1–210

da Costa MA, Campos AC, Coelho JC, et al (2003) Oral glutamine and the healing of colonic anastomoses in rats. *J Parenter Enteral Nutr* 27: 182–5

Department of Health (2015) *2010 to 2015 Government Policy: Obesity and Healthy Eating*. Available online: www.gov.uk/government/publications/2010-to-2015-government-policy-obesity-and-healthy-eating/2010-to-2015-government-policy-obesity-and-healthy-eating (accessed 13 April, 2018)

Demling RH (2009) Nutrition, anabolism, and the wound healing process: an overview. *Eplasty* 9: e9

Dobson J, Williams L (2003) *Nutrition and Wound Healing*. Medical Communications UK, Holsworthy

Edington J, Boorman J, Durrant ER, et al (2000) Prevalence of malnutrition on admission to four hospitals in England. The Malnutrition Prevalence Group. *Clin Nutr* 19(3): 191–5

Flanigan KH (1997) Nutritional aspects of wound healing. *Adv Wound Care* 10(2): 48–52

Guo S, DiPietro LA (2010) Factors affecting wound healing. *J Dental Res* 89(3): 219–29

Han J, Hughes MA, Cherry DW (2004) Effect of glucose concentration on the growth of normal human dermal fibroblasts *in vitro*. *J Wound Care* 13: 140–53

Haughey L, Barbul A (2017) Nutrition and lower extremity ulcers: causality and/or treatment. *Int J Low Extrem Wounds* 16(4): 238–43

Khoosal D, Goldman RD (2006) Vitamin E for treating children's scars. Does it help reduce scarring? *Can Fam Phys* 52(7): 855–6

Langer G, Fink A (2014) Nutritional interventions for preventing and treating pressure ulcers. *Cochrane Data Syst Rev* 6. Art No: CD003216

Lansdown ABG (2004) Nutrition 2: a vital consideration in the management of skin wounds. *Br J Nurs* 13(20): 1199–1210

National Institute for Health and Care Excellence (2012) *Nutrition Support in Adults*. Quality Standard 24. NICE, London.

Nelsestuen GL, Shah AM, Harvey SB (2000) Vitamin K-dependent proteins. *Vitam Horm* 58: 355–89

NHS (2015a) *Live Well; Healthy Eating*. Available online: www.nhs.uk/livewell/healthy-eating/Pages/Healthyeating.aspx (accessed 13 April, 2018)

NHS (2015b) *Change4Life*. Available online: www.nhs.uk/change4life/Pages/change-for-life.aspx (accessed 13 April, 2018)

Perkins P (1992) Wound dehiscence: causes and care. *Nurs Standard* 6(34): 12–14

Scholl D, Langkamp-Henken B (2001) Nutrient recommendations for wound healing. *J Intraven Nurs* 24(2): 124–32

Schultz GS (2000) Molecular regulation of wound healing. In: Bryant RA, ed. *Acute & Chronic Wounds. Nursing Management*. 2nd ed. Mosby, St Louis: 413–29

Sherman AR, Barkley M (2011) Nutrition and wound healing. *J Wound Care* 20(8): 357–67

Singer P (2002) Nutritional care to prevent and heal pressure ulcers. *Isr Med Assoc J* 4(9): 713–16

Timmons J (2006) Skin function and wound healing physiology. *Wounds UK* 1(1): 8–17

Todorovic V (2002) Food and wounds: nutritional factors in wound formation and healing. *Br J Comm Nurs* 7(Suppl 2): 45–54

Wild T, Rahbarnia A, Kellner M, et al (2010) Basics in nutrition and wound healing. *Nutrition* 26(9): 862–6

Williams L (2002) Assessing patients nutritional needs in the wound healing process. *J Wound Care* 11(6): 225–8