**Research Article**

**Nutritional Recommendations for Healthy Patients Undergoing Elective Surgery**

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**Abstract**

**Background and Aim:** The crucial role nutrition plays in postoperative healing has long been established, and accordingly many recommendations have been made to attempt to optimize postoperative recovery for individuals who are malnourished. Similar recommendations have much less commonly been made, however, for individuals who are well-nourished. Therefore, this project sought to provide a set of best-practice postoperative nutritional recommendations for nutritionally appropriate patients undergoing elective surgery.

**Methods:** A literature search was performed to identify relevant articles and resources regarding perioperative nutrition and wound healing. Nutrient lists from the United States Department of Agriculture Nutritional Database were then searched in order to identify foods that have the highest concentrations of the most commonly cited nutrients. Finally, the Center for Nutrition Policy and Promotion Foods Prices Database was used to determine the affordability of each of these foods. These findings were then synthesized to create nutritional recommendations based on the most commonly cited nutrients, specific food sources of these nutrients, and analysis of their affordability.

**Results:** Current evidence indicates that foods high in vitamin C, vitamin A, zinc, protein, and arginine should be consumed in the postoperative period in order to optimize wound healing. Whole foods that contain these nutrients, rather than dietary supplements, are recommended in surgical patients who are otherwise healthy.

**Conclusions:** Through this multi-step process, a set of best practice recommendations to maximize nutrition in well-nourished patients undergoing elective surgeries was developed, with an understanding of the role of important nutrients involved in wound healing.

**Keywords:** Elective surgery; Nutrition; Nutritional recommendations; Postoperative; Practice guidelines; Wound healing

**Introduction**

While much literature exists for malnourished patients undergoing surgery, little has been written about how nutrition can be utilized to optimize the postoperative recovery and wound healing capacity for patients with normal nutritional status. The purpose of this paper is to identify the most commonly cited nutrients associated with wound healing and postoperative period in otherwise healthy patients undergoing elective surgery. The goal was to create a set of best practice recommendations to maximize postoperative nutrition in well-nourished patients undergoing elective surgery, with an understanding of the role of important macro- and micronutrients involved in wound healing.

**Methods**

**Important Nutrients during the Postoperative Period**

An electronic search of Pubmed, Embase, and Web of Science was performed in April 2018, utilizing keywords “Nutrition,” “Postoperative,” “Perioperative,” “Surgical Patients,” and “Wound Healing.” Additional relevant articles were identified searching PubMed through appropriate MeSH terms for the following search items: nutrition, perioperative, postoperative, and recommendations. Only articles published in English were considered eligible. Sixteen articles were identified regarding nutrients during the perioperative period to include in the final qualitative synthesis. Data abstracted from each article included authors, publication year, institution/country, nutrients recommended, and the specific roles in wound healing. The nutrients were then ranked by number of citations. The current recommended dietary allowances (RDA) of these highly cited nutrients were identified in the 2015-2020 Dietary Guidelines for Americans [1].

**Foods High in these Nutrients**

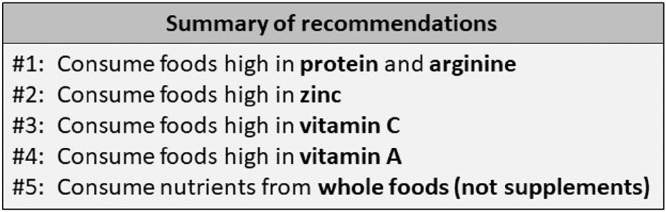
Once the nutrients that were most commonly cited to be beneficial for wound healing, the United States Department of Agriculture’s (USDA) Nutrient Database was used to obtain comprehensive lists of foods containing these nutrients [USDA Nutrient Database]. Data abstracted from the USDA databank included nutrient name, food name, weight, portion size, and nutrient amount.

**Cost Analysis of these Foods**

The USDA Center for Nutrition Policy and Promotion (CNPP) Foods Prices Database was used to investigate the cost of these high-nutrient foods in order to recommend foods that are both affordable and nutritious [USDA CNPP Food Prices Database]. This database presents the average national cost of approximately 4,600 foods using information from the National Health and Nutrition Examination Survey (NHANES), 2003-04; the USDA Food and Nutrient Database for Dietary Studies (CNDDS) version 2.0; the National Nutrient Database for Standard Reference (Release 20); and the Nielsen HomescanTM Consumer Panel.

**Results**

The current available literature was comprehensively reviewed to identify nutrients and food that can optimize healing for the otherwise healthy patient undergoing elective surgery. Vitamin C (cited by 12 articles), zinc (cited by 12 articles), protein (cited by 10 articles), arginine (cited by 10 articles), and vitamin A (cited by 9 articles) were found to be most involved in the tissue healing process. Based on current evidence and the thorough process listed above, 5 key nutritional recommendations were developed (Figure 1). While the nutrients that are thought to be most heavily involved in the tissue healing process are emphasized in this project, it is important to note that recommended dietary allowances should be maintained for all nutrients, not only the ones mentioned in this paper.



**Figure 1:** Summary of key recommendations.

Common food sources highly ranked in these important nutrients using the USDA’s Nutrient Database were ranked by their affordability (Table 1).

**Recommendation #1: Consume Foods High In Protein and Arginine**

Protein has been shown to play the most important role in the wound healing process, as protein is crucial in the synthesis of RNA, DNA, collagen, and connective tissue [2-11]. Accordingly, protein deficiency has been associated with a higher risk of wound healing complications [6]. Increased protein intake has been shown to enhance wound healing rates [3]. Therefore, it is essential to maintain an adequate supply of proteins by consuming minimum recommended dietary allowances. The recommended dietary allowance for protein is 0.8 g/kg body weight, which translates to approximately 46 g/day for females and 56 g/day for males [1]. Proteins are composed of amino acids, and the most commonly cited amino acid involved in wound healing is arginine, which is crucial for collagen synthesis, cell growth, and vasodilation [3,-5,7,8,11,12]. Arginine has also been shown to play a role in modulating immune function [7-10]. There is no recommended dietary allowance available for arginine; however, supplements of 17- 30g have been shown to improve wound healing [9]. Arginine deficiency has shown impaired wound healing [5], while arginine supplementation has been demonstrated to enhance collagen deposition and wound breaking strength [3,7-12]. Arginine supplementation is recommended in states of increased demand, such as patients with wounds [4,8,11,12]. Affordable foods that provide high protein and arginine intake per cost include eggs, meat, poultry, fish, and nuts.

**Recommendation 2: Consume Foods High in Zinc**

The most commonly cited mineral involved in wound healing is zinc [2-5,7-13]. It plays a role in the synthesis of RNA, DNA, and proteins, especially collagen formation [4,5,9-11,13]. It has also been shown to enhance immune function and wound elasticity [3,4,9,13]. Zinc acts as an antioxidant, protecting against free radical damage that can be caused by surgery and anesthesia [13]. The recommended dietary allowance for zinc is 8 mg/day for females and 11 mg/day for males [1]. Zinc deficiency has been shown to delay wound healing and is associated with less wound strength and epithelialization [2,3,5,7,8,11,14]. Zinc supplementation, however, without deficiency lacks proven benefit [4,5,8,9,12]. Excess zinc supplementation can inhibit the absorption of iron and copper, which are other nutrients involved in wound healing [7,8,15]. It is recommended to meet, but not exceed, the RDA intake levels of zinc and this can be accomplished by consuming whole foods high in zinc, such as meat and oysters [14]. Affordable foods that provide high zinc intake per cost include dry beans, oats, seeds, and nuts (including cashews, pecans, and almonds).

Additional minerals have also been shown to have important roles in wound healing, including iron and copper; however, no evidence has been shown to support supplementation of these nutrients for wound healing. Iron acts as a cofactor for antioxidants and collagen formation as well as oxygen transport to the wound tissue [3,5,7, 8,10-12]. Copper is required for collagen cross-linking and angiogenesis, which are important in wound healing [3,8,9,11-13]. Furthermore, deficiency in either of these nutrients has been associated with impaired tissue healing, collagen production, or increased infections [3,5,7-10,12]. Therefore, patients should meet the recommended dietary allowances of these nutrients. Fortunately, many of the foods that have high concentrations of zinc are also high in copper and iron, such as soybeans, lentils, and sesame seeds.

**Recommendation 3: Consume Foods High in Vitamin C**

Vitamin C, also known as L-ascorbic acid, is essential in wound healing due to its role in collagen synthesis, which is crucial in tissue growth and skin repair [2-13]. Vitamin C also acts as an antioxidant, protecting against free radical damage after surgery [3,7,8,13]. Vitamin C also plays an important role in modulating immune function [3-5,7,10]. The recommended dietary allowance for Vitamin C is 75 mg/day for females and 90 mg/day for males [1]. It is particularly important to maintain RDA levels of vitamin C because humans cannot make vitamin C endogenously [16]. Data suggests that many Americans consume vitamin C in amounts less than the estimated average requirement, primarily due to low intakes of food groups that contain vitamin C [1]. Vitamin C deficiency has been associated with longer healing times and increased rates of infections [5,11,12,14]. Vitamin C supplementation, conversely, has been shown to increase collagen production and tensile strength, although supplementation above the daily required intakes have not shown conclusive benefits for non-deficient patients [4,5,8,9]. Vegetables, fruits, and juices are an affordable means of consuming vitamin C. Notable foods high in vitamin C include sweet red peppers, strawberries, oranges, as well as juices (including tomato juice, orange juice, and grapefruit juice).

**Recommendation 4: Consume Foods High in Vitamin A**

Vitamin A also plays an important role in wound healing. It maintains epithelial integrity, increases collagen synthesis, and modulates immune function [3-7,9,11-14]. Like vitamin C, it also acts as an antioxidant, preventing further free radical damage after surgery and anesthesia [13]. The recommended dietary allowance for Vitamin A is 2,300 IU (700 mcg RAE) for females and 3,000 IU (900 mcg RAE) for males [1]. Data suggests that vitamin A is another under-consumed nutrient in the United States [1]. Vitamin A deficiency has been shown to cause impaired wound healing [5,11,12]. Vitamin A supplementation has been shown to provide benefits in wound healing, such as improved epithelialization and collagen formation, even in non-deficient humans [6,7,9,11]. Affordable foods high in vitamin A per cost include vegetables, such as sweet potatoes, carrots, spinach, and mustard greens.

**Recommendation 5: Consume Nutrients Mainly from Whole Foods**

There has been an increasing trend towards dietary supplements, such as multivitamin/multimineral supplements, over the last several years. Multivitamins/multimineral supplements are among the most popular dietary supplements to be consumed [15,17-19]. Data suggests that dietary patterns (the types of foods one eats) are more important than dietary supplements for positive health outcomes [1,15]. Additionally, with dietary supplements, specifically single- nutrient supplements, there is a higher chance of nutrient toxicity and risk of adverse effects if one exceeds the amount of nutrient intake (tolerated upper limit) needed than compared to if one consumes too much of that nutrient from whole food intake [14,17,20]. There can also be a higher chance of nutrient interference, which is when nutrients interfere with each other when taken as supplements but not when taken as foods. For example, excess iron supplementation can inhibit zinc absorption, while excess zinc supplementation can inhibit copper absorption [8,15]. Some patients may experience appetite loss after major procedures, such as abdominal surgery, which could be attributed to the decreased gastric volume and ghrelin. Evidence has shown that postoperative gum chewing can help reinstate an appetite, so patients are more inclined to consume a nutritious diet for better outcomes [21].

Dietary supplements are recommended for those who have increased needs for those nutrients, such as patients with or are “High-Risk” for nutritional deficiencies or those who cannot obtain nutrients solely from a diet of foods [15,20]. Therefore, it is important to assess nutritional inadequacy for the individual patient before determining whether they need a supplement. It is also noted that those who are likely to take nutritional supplements are more likely to have an adequate diet of foods, and that those who are at risk for inadequacy from diet are less likely to be taking supplements [15,19,20]. There has been some controversy about the cost versus benefit balance of adding supplements, especially after the implementation of the 1994 Dietary Supplement Health and Education Act [22]. It is recommended that these dietary supplements be taken on a “as needed basis” and should not be taken in lieu of having a versatile and nutritious diet. With proper use of supplements, a more equal balance can be established with cost and benefit.

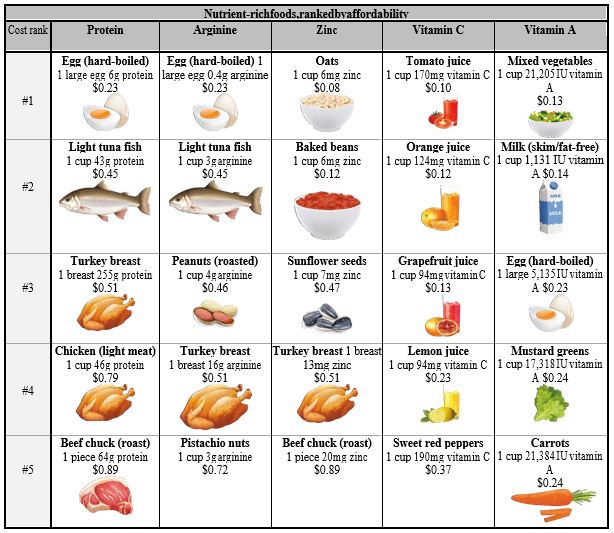
Although data suggests that multivitamin/multimineral supplements are safe for the general population as long as they do not exceed RDA intake levels, most nutritional guidelines, such as the Dietary Guidelines for Americans 2015-2020, maintain that all nutritional needs should be met primarily from foods [1,15]. Additionally, nutrient-rich foods can have other healthy chemical substances not available in supplements, such as flavonoids, phytonutrients, and even substances that have not yet been identified that promote positive health outcomes [23].

Even though demands during wound healing can exceed the RDAs that were created for healthy populations, it is recommended to obtain these nutrients via whole foods due to the additional benefits (phytonutrients, variety, taste, enjoyment, and therefore better quality of life), and micronutrient supplements are best suited when nutrient requirements are not met through diet alone [1,15].

**Discussion**

During the postoperative period, it is especially important to meet the daily RDA intake of these nutrients essential in wound healing that have been noted in this paper. For many of these nutrients, it is only necessary to meet the daily RDA intake. For other nutrients, supplementation higher than the RDA intake may be beneficial-such as for protein, arginine, and vitamin A- although the evidence of this is incomplete or conflicting.

In addition to foods that are nutrient-rich, research has shown that it is important to consider those foods that are also affordable as well as culturally acceptable. While some of the foods we mention have very high concentrations of a particular nutrient important in wound healing, it is less likely that consumers will eat these foods if they are not affordable, accessible, or culturally acceptable [24,25]. In fact, the nutritional value of a food item has been reported to be less relevant to adults than the taste and cost of the item [1,24-26]. The affordability of a food item often plays a tremendous role in food choice. Therefore, the cost of foods that had high amounts of these essential nutrients was considered and factored into (Table 1).



**Table 1:** Foods sources of critical nutrients involved in tissue healing, with serving size, nutrient amount per serving, and price ($/100g).

Some foods are naturally high in concentration of several nutrients critical for wound healing and therefore may be considered to be potential “superfoods” for wound healing. These foods included: turkey breast, eggs, sweet red peppers, and kidney beans. However, some of these foods may be difficult to access for the general public as they may not be locally available, affordable, or culturally acceptable.

In recent decades, attention to perioperative nutrition has grown in importance and more professionals work to achieve an optimal nutritional state for the patient to enhance surgical outcomes and recovery. A good way to promote this optimal health for patients is by sharing established evidence about nutrition and its indications in scientific journals. This analysis highlighted the importance of nutritional guidelines for the postoperative period. A comprehensive literature review of the available evidence was performed, which allowed the creation of recommendations of important nutrients as well as affordable foods that can be used universally for otherwise healthy patients after surgical procedures.

**Conclusion**

For otherwise healthy patients undergoing elective surgical procedures, a healthy postoperative diet that likely optimizes wound healing consists of vitamin C, vitamin A, zinc, protein, and arginine. Specific foods that provide these nutrients and are also affordable were identified, and these foods were highlighted via a newly developed set of best practice recommendations that can be easily and inexpensively adopted.

**Conflict of Interest**

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

**Author Contributions**

All authors made significant contributions to the content, synthesis, and organization of the paper. The manuscript has been seen and approved by all authors. The content of this article has not been submitted or published elsewhere.

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