Annals of Clinical and Medical Case Reports[R] ISSN 2639-8109 |Volume 15

Case Report Open Access

Mapping the Impact of Postoperative Malabsorption on Chronic Wound Healing: A Scoping Review of Evidence Following Gastrointestinal Resection

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Received: 02 Feb 2026
Accepted: 11 Feb 2026
Published: 16 Feb 2025
J Short Name: ACMCR

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Highlights:

1. Postoperative malabsorption after gastrointestinal resection slows chronic wound healing by limiting essential nutrient absorption.
2. Deficiencies in protein, zinc, iron, and vitamins A, B_{12}, C, D, E, and K impair inflammation control, collagen formation, and tissue repair.
3. Early enteral feeding within 24–48 hours improve wound closure and reduces postoperative infection risk.
4. Combining enteral, parenteral, and immunonutrition enhances healing and shortens hospital stays.
5. Standardized interdisciplinary nutrition and wound-care protocols improve recovery and long-term surgical outcomes.

Keywords:

Postoperative Malabsorption; Gastrointestinal Resection; Chronic Wounds; Wound Healing; Nutritional Deficiency; Enteral Nutrition; Parenteral Nutrition; Immunonutrition; Enhanced Recovery After Surgery (ERAS) and, Surgical Site Infection.

Citation:

Zohair Siraj, MS, Mapping the Impact of Postoperative Malabsorption on Chronic Wound Healing: A Scoping Review of Evidence Following Gastrointestinal Resection. Ann Clin Med Case Rep® 2026; V15(1): 1-17

1. Abstract

1.1. Background

Chronic wounds often fail to progress beyond the inflammatory phase and are made worse by nutrition deficits. Gastrointestinal resection can cause postoperative malabsorption of protein, fat soluble vitamins, B complex vitamins, iron, zinc and electrolytes, which can delay tissue repair, angiogenesis, collagen synthesis and immune defense. The clinical impact of resection related malabsorption on wound healing and the effectiveness of nutrition strategies after surgery have not been exhaustively mapped.

1.2. Methods

The research followed the PRISMA-ScR guidelines for its scoping review. The research team searched for studies through PubMed, Google Scholar, FRAML, Web of Science, Scopus and Cochrane Library until July 2025. Search terms combined GI resection, malabsorption/malnutrition, nutrients and wound outcomes. We excluded non-GI surgery, animal/in-vitro work, and secondary analyses without original cohorts and papers without postoperative outcomes. 181 records were screened, 63 excluded at title/abstract and 38 at full text for missing clinical or wound related data. 80 studies were included. Data was chart-

ed for surgery type, population, nutrition status/intervention and outcomes (wound healing rates, infections, immune markers, length of stay).

1.3. Results

Malabsorption was common after gastrectomy, esophagectomy and small bowel resection, with frequent deficits in protein, fat soluble vitamins, vitamin B12, iron and zinc. Lower albumin and hemoglobin were associated with infections, prolonged ileus and slower closure. Early enteral nutrition (within 24-48 hours) reduced infections and length of stay versus parenteral nutrition, and several cohorts reported faster wound closure with enteral or combined enteral-parenteral support. Immunonutrition (e.g. arginine, glutamine, omega-3 fatty acids) was associated with fewer infectious complications in select groups. However, study designs were heterogeneous, with inconsistent wound outcome definitions and variable nutrition targets (e.g. protein 1.2–2.0 g/kg/day). Resource limitations and care coordination gaps (variable ERAS adherence, under dosing of supplemental PN, limited follow up) hindered implementation.

1.4. Conclusions

Malabsorption after GI resection is associated with delayed wound healing and increased infection risk. Early enteral feeding, accurate protein targets and targeted micronutrients appear beneficial, but fragmented reporting, variable protocols and fewer high quality trials limit guidance. Prospective studies with standardized wound outcomes and nutrition dosing, enteral-parenteral combinations, and implementation research to address resource and training gaps are necessary to optimize recovery in this population.

2. Introduction

Chronic wounds are a result of many causes including traumatic, pressure, surgical, and vascular wounds as well as infections, diabetes, medications and nutritional deficiencies [1]. These wounds do not follow the normal healing stages and may not be able to progress past the inflammation stage. By addressing the underlying cause(s) along with the right treatments, chronic wounds can heal although they may take much longer, from months to years, hence the term "chronic."

Systems such as the circulatory, immune, integumentary, nervous, and digestive are a few involved in the wound healing process. Of these, the digestive system plays a crucial role in providing the nutrients and energy required in the wound healing process [2]. Therefore, malnourished individuals are at a higher risk for the development of chronic nonhealing wounds.

The four stages of wound healing are haemostasis (clot formation), inflammation (clearing of debris and pathogens), proliferation (tissue formation and angiogenesis), and remodeling (collagen synthesis and fibrosis). Each step requires certain macro- and micronutrients to regulate the work of healing including Vitamins A, B, C, D, E, K, zinc, and proteins [3-6].

Many of these essentials are attained through the diet as food is broken down and nutrients are absorbed through the gastrointestinal (GI) tract [2,3].

Several common and rising complications like tumors, infections, damage, obstructions, and bariatrics require the need for a resection in the GI system where certain portions of the GI tract are removed through surgery to resolve the issue [1,7,8]. Postoperative complications of resection frequently involve malabsorption syndromes, a few being steatorrhea, dumping syndrome, and short bowel syndrome [1,9,10]. Along with a loss of gut microbiota, mucosa, length and surface area, resection of specific parts of the GI tract diminishes its ability to absorb the necessary nutrients contributing to a reduction in effective healing [2,5,6,9] For example, the ileum is the main site of absorption for Vitamin B12. Resection of it would lead to malabsorption and deficiency of vitamin B12, leading to delayed healing, as B12 is crucial for healing processes, namely cell regeneration and collagen production [1,5,6]. Without supplemental nutrients and proper management, resection of various parts of the GI tract may result in chronic wounds (existing or future) with persistent symptoms such as unresolving inflammation, purulent discharge, pain, foul odor, and more [5]. With a growing concern for the downstream effects of postoperative malabsorption, this review aims to examine how malabsorption, as a result of GI resection, compromises wound healing. It further serves to delve into evidence-based data on the possibilities of nutritional and clinical interventions that may mitigate these complications and improve outcomes. Specifically, the objective of this scoping review is to map existing evidence on the relationship between GI surgery-induced malabsorption and chronic wound healing outcomes.

3. Methods

A comprehensive literature search was conducted using the databases PubMed, Google Scholar and ScienceDirect. Search terms included combinations of "gastrointestinal resection," "nutrition," "malnutrition," "albumen," "postoperative recovery," "wound healing," "mortality," "immune response," "malabsorption," and "intestinal adaptations." Boolean operators and MeSH terms were used where applicable. Searches were limited to the following: those published between January 2010 and July 2025, human studies, English language, and

peer-reviewed journals.

A total of 181 articles were identified across all databases, and the titles and abstracts were screened after 5 duplicate articles were removed. Articles were excluded if they were: Literature reviews or meta-analyses, focused on non-GI surgical procedures, conducted in animal or in vitro, or secondary data analyses without original cohort. After the screen, 62 articles were removed based on the above criteria. The remaining 118 full-text articles were retrieved and reviewed for eligibility. Articles were excluded if they: lacked human clinical data, failed to address nutritional or wound healing, focused solely on critically ill patients, did not provide postoperative outcomes [41]. articles were removed, and 73 articles were included in the final review.

For each of the articles included, the following data was compiled: author, year, study design, population characteristics and type of GI surgery performed, nutritional intervention or variable studied, primary outcomes, postoperative recovery metrics (wound healing rate, length of hospital stay, immune markers, infection rate), and secondary outcomes, particularly, biochemical or physiological effects of nutritional status.

Due to variations among study design, sample sizes, reported outcomes and patient populations, a qualitative synthesis approach was used rather than a meta-analysis. Studies were grouped by surgical type, nutritional deficiency, and wound healing outcome. Tables and figures were used to visualize prevalence rates, nutrient deficits, and clinical outcomes.

Table 1: Summary of Inclusion and Exclusion Criteria.

Domain	Inclusion Criteria	Exclusion Criteria
Population	Adult patients (≥18 years) undergoing gastrointestinal (GI) resection	Pediatric patients (<18 years); patients with unrelated conditions (e.g., HIV, stroke)
Study Design	Randomized controlled trials (RCTs), observational studies, case reports/series	Literature reviews, meta-analyses, animal studies, in vitro experiments
Setting	Clinical settings involving GI surgery and postoperative recovery	Non-surgical settings; studies not involving GI resection
Intervention	GI resection procedures with documented malabsorption or nutritional follow-up	Non-GI surgeries; studies lacking nutritional or wound healing context
Outcomes	Postoperative wound healing metrics (e.g., healing rate, infection, immune markers)	Studies without wound healing outcomes; no postoperative data; no nutritional linkage
Language	English or English translation available	Non-English without translation
Publication Date	Published between January 2010 and July 2025	Published before 2010
Data Type	Original clinical data (cohort, RCT, case series)	Secondary analyses without original data; modeling-only studies

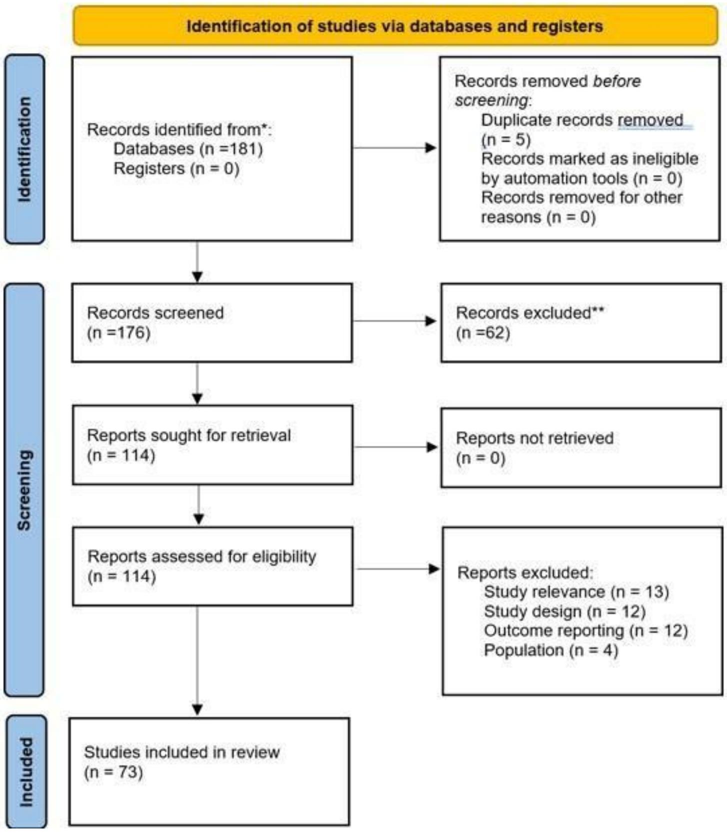

Figure 1: PRISMA Diagram.

3.1. Epidemiology and Clinical Burden of Malabsorption Post-GI Surgery

After undergoing gastrointestinal surgeries, many patients experience major changes and fluctuations in their digestion, absorption, and metabolism. These complications can be either intended or unintended according to the type and goal of the original procedure. However, one serious complication that is normally unintended is malabsorption. Malabsorption is a common issue after gastrointestinal surgeries. It impairs the body's natural ability to absorb essential nutrients. Gastrointestinal procedures usually affect many aspects of metabolism such as gastric acid secretion, bile movement, and enzyme production, which can directly cause malabsorption. The global prevalence of malabsorption depends on many factors, with the most significant being the type of surgery performed and the demographics of patients. Gastrectomies, esophagectomies, and small bowel resections are three common procedures that may later result in malabsorption in many patients (Table 2). Following gastrectomy, fat malabsorption occurs in almost all patients, and vitamin B12 deficiency usually develops in less than one year [11]. After esophagectomy, 25–46% of patients show sign of major weight loss within three years [12]. While in small bowel resection, short bowel syndrome may develop, which is an inability to absorb nutrients. Although rare, short bowel syndrome is severe and causes loss of many important fluids, electrolytes, and vitamins [13].

Postoperative malabsorption is also a major problem in causing the deficiency of iron, zinc, protein, fat-soluble vitamins, vitamin C, and vitamin B12. One study shows that deficiencies in vitamin A, zinc, and iron can cause cognitive issues, diseases related to aging, and problems in muscle and skeletal growth [14]. In addition, protein deficiency can slow down wound Healing [3]. Lastly, iron and vitamin B12 deficiencies result in anemia, especially in females. Specifically, after undergoing total gastrectomy, patients have experienced a strong likelihood of developing iron deficiency (Table 2). Fat malabsorption is also very common and can occur in almost all patients after a gastrectomy [15].

Nutrient deficiencies and postoperative malabsorption are strongly linked with slower healing of chronic wounds. Generally, this can be because essential nutrients play a significant role in powering processes such as inflammation, synthesis of collagen, and fibroblast migration. Vitamins B, C, D are important for inflammatory processes and synthesis of collagen [3]. Proteins are required in the immune processes. Vitamin A is required for high function of B cells and T cells. Zinc is useful to fight against infections because it has a major role in recruiting Antibodies [3]. Given the importance of the mentioned nutrients, post-operative low levels significantly delay tissue recovery. Moreover, untreated long-term malabsorption can also cause infection risk in postoperative patients.

The characteristics of post-operative malabsorption often differ based on both the nature of the surgical procedure and patient demographics. It is noted that procedures which result in total resections cause the greatest, eventual nutrient loss. One study observed 376 patients who had a gastrectomy. It was shown that their postoperative weight loss depended on both the patient's individual BMI and the extent of gastric resection. A greater amount of resection was associated with greater weight loss [15]. On the other hand, demographics also matter. Females, the elderly, and low BMI patients are more likely to suffer malabsorption. This is because females are prone to iron deficiency, and the elderly often have vitamin B12 deficiency [16]. Consequently, close, individual assessment by clinicians is very important to identify patients who might be at higher risk. This would allow for a focus on bringing awareness to the patients and their families and educating them on complications that may occur post surgery. Several studies have suggested socioeconomic status (SES) to be yet another factor in exacerbating post-operative malabsorption. One such study identified a notable positive correlation between an individual's SES and vitamin D in their daily diet, proving the relevance of SES [17].

When we explore postoperative malabsorption in a more global aspect, it is obvious that this complication is more common in lower resourced countries. This may be due to an apparent shortage of doctors in these areas as they are the ones who usually order dietary supplements, provide nutritional counseling, and encourage follow-ups. A study in Ireland highlighted the high levels of vitamin D deficiency amongst patients residing in a disadvantaged area [17]. In contrast, locations with high income individuals and well equipped hospitals displayed lower malabsorption rates. Regionally, the United States has the highest postoperative malabsorption syndrome rates. This may be due to the fact that the United States performs the highest number of bariatric surgeries annually [18].

One important aspect to note is that both monitoring and patient follow-up for post-operative malabsorption are impacted by disparities. In regions that may be secluded or lack resources, there is usually a shortage of clinicians such as dieticians, physicians, and nurses. Therefore, follow-ups could be commonly delayed, reducing the motivation to visit a doctor. Hospitals in these low socioeconomic regions may also lack access to sufficient micronutrient testing and supplements. One study illustrated how socioeconomically disadvantaged patients are less likely to have proper follow-up care [19]. Many factors come into consideration here, with the most significant ones being: limited resources for traveling to the hospital, preoccupation with more pressing responsibilities (such as children, etc.), and high service costs. Unfortunately, a lack of patient follow-up leads to higher rates of chronic nutrient deficiencies. In contrast, countries who may have large healthcare systems often have many adequate resources and clinicians. There is no lack of doctors and screenings are often encouraged. In the end, it is important to increase awareness as well as to continue addressing the underlying healthcare disparities.

Table 2: Nutrient Deficiencies and Prevalence Rates by Surgery Type.

Surgery Type	Common Nutrient Deficiencies	Prevalance
Gastrectomy (partial or total removal of the stomach)	Vitamin B12, Ioron, Fat - Soluble vitamins (A, D, E, K), Protein	Fat Malabsorption Occurs in nearly all patient; Vitamin B12 Deficiency develops within 1 year; iron deficiency is common in females.
Esophagectomy (Partial or total removal of the oesophagus)	Protein, Iron, vitamin B12, Zinc	25-46% of patients experience severe weight loss within 3 years postoperatively.
Small Bowel Resection (Removal of a portion of the small Intestine)	Fat-soluble vitamins (A, D, E, K), B12, Iron, Zinc, Electrolytes	Short bowel syndrome may develop (rare but severe), leading to chronic nutrient and fluid loss.

3.2. Pathophysiologic Mechanisms Linking Malabsorption to Impaired Wound Healing

3.2.1. Overview of Wound Healing Phases: Inflammation, Proliferation, Remodeling

Tissue repair represents a biological process that restores structure and functional integrity after an injury. It usually has three phases that occur somewhat at the same time: inflammation, proliferation, and remodeling (Figure 1). Each part involves different cell actions, the release of substances, and changes to the extracellular matrix. Following an injury, the inflammatory response begins with increased permeability in blood vessels. Neutrophils migrate to the injury site, while macrophages remove debris and secrete enzymes. Present studies show that pro-inflammatory macrophages are located at the wound's edge [20]. The macrophages release EGFR-ligands and chemokines that assist the movement and re-epithelialization of keratinocytes. During proliferation, keratinocytes increase in number and migrate to cover the wound. At the same time, fibroblasts create an extracellular matrix that becomes granulation tissue. Endothelial cells are essential for starting the creation of new capillaries. A migrating front that does not proliferate is supported by a group of keratinocytes that do proliferate. Proliferating fibroblasts release growth factors that further aid migration [21]. Next is remodeling, which involves the matrix reorganizing and becoming stronger, fibroblasts crosslinking and modifying granulation tissue to strengthen the extracellular matrix, changing towards tissue maturation [22].

3.2. Collagen Synthesis

Many nutrients play a key role in the formation and structure of collagen. When the body shifts its resources that are normally meant to maintain the collagen matrix, it experiences nutrient deficiency leading to a rise in oxidative stress. With the lack of necessary nutrients, collagen production falls, hindering the process of tissue repair [23].

Kim et al. [24], did a study in South Korea with 87 adults, including 40 with full-thickness rotator cuff tears. They measured factors such as fasting lab results (B12, vitamin D, homocysteine, minerals), DXA bone density, and MRI tear measurements. The group with rotator cuff tears had lower B12 levels. The researchers found that low levels of vitamin B_{12} cause homocysteine levels to increase, disrupting the structure of collagen. It also leads to more inflammation and oxidative stress, which can further damage collagen by affecting cytokine production and antioxidant actions. Likewise, low levels of vitamin D_3 causes mineral imbalance, needed for collagen [23]. It does so by downregulating receptors in the kidneys and bones, weakening FGF23 signals, and lowering serum phosphorus. Furthermore, weak blood vessels and slow wound recovery can disrupt hydroxylation, an important step in collagen synthesis. This is due to a lack of vitamin C [24].

3.3. Angiogenesis

Angiogenesis, or the formation of new blood vessels, begins when endothelial cells (ECs) activate, multiply, migrate, and stabilize. Proangiogenic signals can be inhibited by a lack of energy and nutrients, which lowers EC activity [25]. In their 2021 study, Tsuruoka et al. (2021) employed mice lacking zinc.[26] They discovered that

the mice recovered from blood flow blockage more slowly, had fewer capillaries in their injured muscles, and had lower levels of VEGF mRNA. These problems were a sign of inadequate angiogenesis. NADPH-oxidase activity and oxidative stress were also elevated in the mice. Upon decreasing NADPH oxidase levels, decreased ROS levels and improved blood vessel growth was observed. This implied that zinc plays a key role in angiogenesis.

Narayanan et al. (2013) utilized human umbilical vein endothelial cells (HUVECs) and a rabbit assay to inhibit CTR1, an endothelial copper transporter [27]. They noticed that less copper inside the cell decreased the growth of cells, movement, tube creation, and VEGF expression in HUVECs. This demonstrated how angiogenesis relies on copper, suggesting that low copper levels impair angiogenic responses. The researchers came to the conclusion that angiogenesis impairment caused by nutrient deficiencies can cause a disruption in the development of new vessels.

Since endothelial cells require specific material to proliferate, migrate, and form new vessels, both studies show that inadequate nutrient intake impairs angiogenesis. Zinc helps control oxidative stress; if it is depleted, endothelial cell death increases while VEGF expression decreases. Maintaining the strength of the extracellular matrix (ECM) is crucial and calls for factors such as copper for integrity.

3.4. Fibroblast Activity

Fibroblasts play a major role in constructing and remodeling the extracellular matrix, consisting of a contractile (α-SMA^{+}) phenotype, driving wound healing, and keeping tissue structures intact. Łabędź et al. [27] performed a study on mice, using BALB/c and C57BL/6 strains (with n=4–7 per group based on the assay). Said strains were administered through diets containing vitamin D_3 at normal levels (1000 IU/kg), deficient levels (100 IU/kg), or supplemented levels (5000 IU/kg) [28]. Some mice received calcitriol at a dose of 1μg/kg. Investigators then isolated lung fibroblasts and tumor cancer-associated fibroblasts (CAFs) and profiled activation markers (α-SMA, podoplanin, PDGFRβ, tenascin-C). In mice that were fed vitamin D-deficient diets (100 IU) and then given calcitriol, fibroblasts in the 4T1/BALB/c model shifted toward a more activated, myofibroblast-like state (↑α-SMA, podoplanin, tenascin-C), while high vitamin-D_3 intake (5000 IU) muted several activation signals. In the E0771/C57BL/6 model, the addition of supplementation led to an increase in CAF activation, while calcitriol administered on a control diet resulted in a reduction of α-SMA. The researchers suggested that Vitamin D influences how fibroblasts behave. If Vitamin D levels are low, fibroblasts can become overactive or respond incorrectly to signals, promoting fibrosis. This can cause either too much contraction or a disorganized matrix, possibly delaying regular wound repair.

A study done at Northwest A&F University by Yan et al. [28] divided 14 laying hens into 2 groups as a controlled experiment [29]. One group received a vitamin D_3-restricted diet (0 IU/kg), and the other group a standard diet standard diet (1,600 IU/kg). The researchers then observed the hens' handling of minerals (phosphorus, calcium, alkaline phosphatase levels in their blood), and endocrine signals (FGF23, PTH, 1,25 $(OH)_2D_3$). They also analyzed transporter expression (renal NPt2a; intestinal NPt2b), and receptor pathways (FGFR1–4, Klotho, VDR) in bone (calvaria), kidney, and intestine. Lastly, the hens' feces were monitored for calcium and phosphorus levels. According to the results, the investigators noted that Vitamin-D_3 restriction lowered serum phosphorus (~31%) and FGF23 (~15%) and increased alkaline phosphatase (~4×). It also downregulated FGFRs and VDR in calvaria, FGFR1/FGFR4/Klotho/VDR in the kidneys, and decreased renal NPt2a protein. It was concluded that short-term vitamin-D_3 deprivation suppresses the FGF23–FGFR–Klotho–VDR axis and disrupts phosphate handling.

These conditions can shift fibroblast signaling and matrix metabolism in ways that are unfavorable for orderly repair. Hence, in a malabsorption state, these shifts lead to poorer collagen remodeling by fibroblasts and slower remodeling.

3.5. Immune Response

Inadequate nutrition makes the body unable to effectively detect and combat the actions of invading microorganisms and alters the responses of all the body's defence mechanisms, resulting in either poorly regulated or inferior inflammatory responses. If the state of malnutrition is acute, it can fail to provide adequate stimulus for the immune processes to function effectively, and hence the position of infection cannot be returned to a condition of balance [30]. Studied a group of hospitalized children suffering from severe malnutrition [31].

They showed that in these children, there was a rise in the pro-inflammatory cytokines such as IL-8 and TNF-α. At the same time, a deficient bacteriostatic or bactericidal effect was seen because of low concentrations of amino acids such as branched-chain (BCAA), essential, and urea-cycle amino acids.

A decrease in protein and amino acids leads to a dysregulation of the immune response by disrupting homeostasis and causing neuroinflammation. Neuroinflammation is worsened through glial cells being constantly activated. In a state of amino acid deficiency, the body can't make enough signaling molecules, immunoglobulins, and cytokines, leading to constant inflammation or neuroimmune disorders in tissues [31].

3.6. Role of Protein-Energy Malnutrition and Micronutrient Deficits

In protein-energy malnutrition (PEM), there are not enough proteins and cofactors to assist in wound repair. This leads to a halt in progression of the healing phases (Figure 2). Protein deficiencies during inflammation cause weakened immune signaling and slow neutrophil and macrophage response at the wound site(s). This makes the inflammatory response last longer and makes it harder to get rid of debris. Diets low in protein decrease cytokines like TNF-α and the body's defenses weaker [32]. Severe protein and micronutrient deficiency presents with reduced or absent collagen formation, angiogenesis, and fibroblast generation during various wound healing phases. This weakens tissues and prevents repair and can be extremely detrimental to healing, contributing to chronic wound development. A nutrient-rich formula that includes collagen, minerals (iron), and vitamins (mainly C, E, and B12) can extend the healing time for wounds in standard wound care [33]. This shows how nutrients play a critical role in supporting the extracellular matrix and enhancing wound repair.

Figure 2: Wound Healing Phases.

Figure 3: Nutritional Deficiencies Effecting Wound Healing.

3.7. Nutritional Interventions and Supplementation Strategies

3.7.1. Enteral vs. Parenteral Nutrition in Malabsorptive Patients

Enteral nutrition is preferred over the parenteral nutrition route. This is to ensure adequate nutrient intake in malabsorptive patients who have recently undergone gastrointestinal (GI) resection surgery [34]. It was shown that enteral nutrition had significantly lower rates of infection than those receiving parenteral nutrition intake. One study performed by Zhang et al. [36], had found that enteral nutritional intake reduced the odds of infections by 41% when compared to parenteral nutrition [35]. However, there is an increased risk of GI complications, such as vomiting and diarrhea, which could lead to suboptimal nutritional intake [36]. It was concluded that in the instance of suboptimal nutrition, supplemental parental nutrition can be added to enteral nutrition. However, this dual action therapy should be started earlier rather than later due to the decrease in metabolic needs being met, as well as increased risk of infection [37].

3.8. Evidence-Based Supplementation

Due to the increased malabsorptive conditions in these patients, they are seen to quickly develop micronutrient deficiencies, despite receiving nutrients through enteral nutrition. Depending on which part of the GI tract has been dissected, patients can be at a higher risk for certain vitamin deficiencies. For example, patients with ileal resection see increased risk of fat-soluble vitamin deficiencies. Furthermore, those with small bowel resections, particularly the jejunum, see increased vitamin C, and many vitamin Bs, unable to be absorbed, leading to deficits. Patients are given Commercial Enteral Formulas (CEFs), which are tailored to ensure proper nutrients are received. However, it is noted that not all CEFs deliver the same amount of nutrition, as some may experience formula loss during transport, or incomplete dosage administration [38]. According to Ricci et al. [39], administration of CEF containing supplements with glutamine, arginine, and omega-3 fatty acids reduces morbidity and complication rates after surgery post-operatively [39]. In a study done by Stanescu et al, it was shown that patients beginning enteral nutrition post-op should receive a wide array of nutrient supplementation as well. These supplementation regimens should include various vitamins, minerals, and amino acids (listed in Table 3). One important factor to consider is protein. It is essential to monitor protein intake depending on a patients' height and weight. Adequate protein intake is vital in decreasing wound healing time. It is recommended that patients receive 1.2-2.0 g/kg of body weight per day [40]. One study showed that by meeting the protein energy targets, it exhibited a 50% decrease in 28-day mortality [41]. When patients received this supplementation, they experienced overall improved wound healing outcomes and enhanced therapeutic strategies.

3.9. Timing and Dosage Considerations for Post-Surgical Patients

Patients should be started on early enteral nutrition within 24-48 hours, according to the European Society for Clinical Nutrition and Metabolism (ESPEN) and the American Society for Parenteral and Enteral Nutrition (ASPEN) guidelines [41,42] In post-op surgical patients, pro-inflammatory factors significantly increase with malnutrition. This inflammation often leads to a significant delay in overall wound healing, increased days spent in the hospital, and an increase in both wound and blood infection complications [43]. According to an analysis by Fukatsu (2019), use of early enteral nutritional and supplemental interventions reduces the risk of infectious complications after surgery by up to 50% [44]. The decrease in infections is linked to enteral nutrition, improved gut immunity, and hepatic immunity post-operatively. This study also states that 15% of total energy received via enteral nutrition is enough to maintain and manage gut morphology and immunity.

Table 3: Suggested Enteral Nutrition Vitamin Supplementation in post-operative Abdominal Resection Patient.

Nutrient	MoA	Population	Outcome
Protein	Tissue repair	All patients, post-operative abdominal resecction	Increases wound heling\decreases overall time spent in hosptial
Glutamine	Increases gut barrier, immune cell support	Post-operative, particularly malnourished and\or high-risk individuals	Preserves/Increases mucosal barrier
Arginine	Immune modulation	Most patient post operative abdominal resection\Increases wound healing	Vasodilation, protein production, Circulation\Increases inflammation
Omega-3 Fas	Anti-inflammatory, Immune modulation	ICU patients	Reduces post-operative inflammation
Zinc	Enzyme cofactor, increase immune functionality	Patient experiencing severe deficiency states	Immune cell function/increases wound healing

3.10. Clinical Outcomes

Enteral nutrition has contributed significant benefits to patients' overall healthcare experience post-op. Baik et al. [45], showed that early enteral nutrition (24-48 hours) had a significant reduction in hospital length of stay by 1.15 days [45]. This study also showed a moderate reduction in ICU length of stay of 0.18 days. Furthermore, it was noted that overall new infections were decreased by 13%, and bloodstream infections decreased by 27% (compared to parental). When compared to parenteral nutrition, patients receiving enteral nutrition had significantly quicker wound closure rates. One randomized control trial (RCT) conducted on 78 patients with

post-operative abdominal surgery fistulas showed a 60% closure rate over 37% parenteral nutrition closure rate [46]. This concluded that patients were 2.6 times more likely to have their wounds close than those with parenteral nutrition. Median closure timing was 27 days during this study. Therefore, enteral nutrition had much higher closure rates, and shorter closure times than those with parenteral nutrition.

3.11. Surgical and Postoperative Factors Affecting Nutritional Status

3.11.1. Influence of Technique on Malabsorption Severity

One study included 137 pediatric patients, each with one of 3 types of short bowel syndromes (SBS) due to conditions such as atresia, necrotizing enterocolitis, long segment Hirschsprung disease, gastroschisis, and midgut volvulus. The three types of bowel anastomosis surgeries used in the gastrointestinal (GI) resection procedures included jejunostomy, jejuno-colic anastomosis, and jejuno-ileal anastomosis. After surgery, all patients required full parenteral (PN) nutrition.

Median treatment averaged 36 years where outcomes varied depending on type of anastomosis and end of treatment care. The results of the Dreuille et al. [47], study indicated that the presence of an intact colon lead to faster improvement and return to non PN nutrition [47]. The length of bowel remaining also saw reduced weaning periods as individuals who had less bowel removed returned to non PN nutrition before those with longer bowel resections. Individuals that required PN nutrition before resection in all types of resections were not a predictor of the length of weaning periods required at the end of treatment. It is important to distinguish in this study that PN nutrition consisted of non-protein intravenous nutrition and all patients of this study began with the same PN nutrition after gastrointestinal (GI) anastomosis surgery [47]. In a 2024 study based in Japan, 27 more patients with SBS (excluding those diagnosed with Crohn's disease) were observed. Of the 27 patients in the study, 14 of the patients died within 1 year of GI resection. Of those 14 that died, rates of jejunostomy and PN nutrition dependence were high, signifying decreased outcomes of jejunostomy patients. 13 of the 14 patients of this death group received jejunostomy anastomosis in which they averaged a residual bowel length 20 cm shorter than their surviving cohort. Several causes of death were found for the individuals in the death group, the two most prevalent being multiple organ failure attributed to a mixture of other chronic illnesses in addition to GI resection, and dehydration or electrolyte imbalances. Individuals who received GI anastomosis surgeries all experienced some prevalence of malabsorption at some point, however those who received jejunostomy surgeries reported an increase in dehydration, electrolyte imbalance, reduced drug absorption, and gall stones [48]. It is important to note that the median age of the 2024 SBS single-center study was just over 55 years of age, significantly higher than that of the pediatric study. Even though the median ages of these groups were drastically different, some major conclusions were observed across each: patients with less residual bowel present (especially those with jejunostomy anastomosis procedures) and individuals who remained dependent or could not be weaned off of PN nutrition had worse outcomes [48].

3.12. Post Operative Monitoring Protocols for Nutrition

Monitoring of nutrition status post GI resection surgery can be difficult. With the development of the Enhanced Recovery After Surgery (ERAS) protocol, most nutritionists now agree that early return to enteral eating is important in bowel healing and recovery. While most individuals require PN nutrition post-operation, those who return to enteral nutrition sooner generally have better outcomes compared to their counterparts. Early enteral nutrition starts peristalsis and bowel function, leading to increased blood flow. ERAS protocol also indicates reduced morbidity after laparoscopic surgery. After review, it is now generally agreed upon that preoperative nutrition is important for GI resection prospective patients as many of these patients are already victims of malabsorption or nutritional deficits which leads to higher risk of developing septic complications. GI resection patients undergo delayed enteral feeding due to side effects of the procedure, some of which are swelling, obstruction, or impaired gastric emptying. They are typically required to receive PN nutrition and therefore it is important to provide adequate nutrition to patients preemptively and to introduce enteral nutrition as soon as possible [49]. The introduction of early enteral nutrition led to significantly higher nutritional markers such as albumin and hemoglobin. These individuals adhered to the ERAS protocol and saw reduced times to their first flatus and bowel movements, indicating a significant improvement in postoperative recovery [50].

Another trial, the SONVI trial, compared immunonutrition versus the standard high-protein and hypercaloric nutrition that is currently in use. The main findings of this trial revealed that immunonutrition supplementation resulted in fewer infectious complications [51].

Overall, the extent of postoperative monitoring for GI resection patients consists of duration from surgery to first flatus and bowel movement. Close monitoring of wounds and wound care, blood panels measuring hemoglobin, albumin and prealbumin, white blood cells, inflammatory markers are other primary monitoring criteria. Intervention between physicians and nutritionists to quantify intake of macronutrients and creating a future care plan is also critical in GI resection monitoring. Figures 1-4 show a comparison between control groups who received total PN nutrition without ERAS protocol and the observed group where Nasojejunal tubes were placed for total enteral nutrition. Graphical analysis shows that the observed group who received enteral nutrition had shorter times to first flatus, shorter times to first bowel movement, and higher nutrition markers 5 days post operation [50].

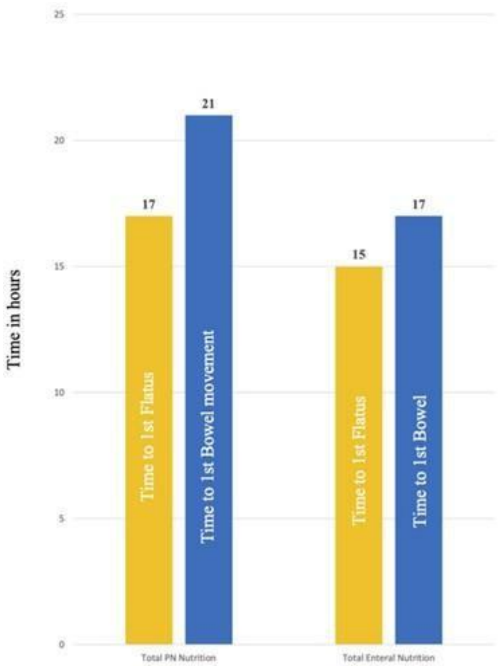

Figure 4: Comparison of Recovery via frist flatus and bowel movement.

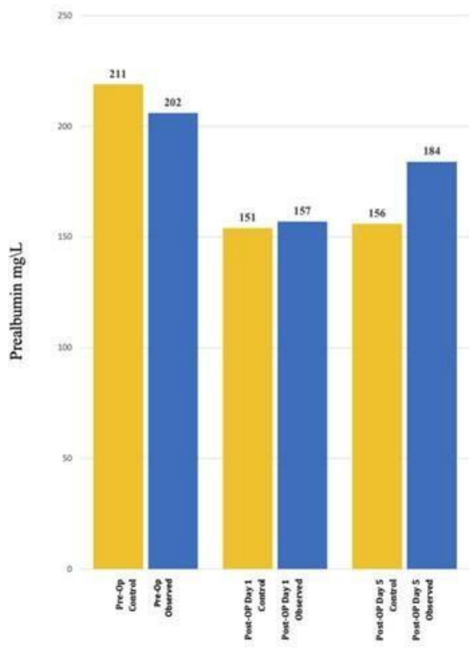

Figure 5: Comparison of pre-and post-operative prealbumin.

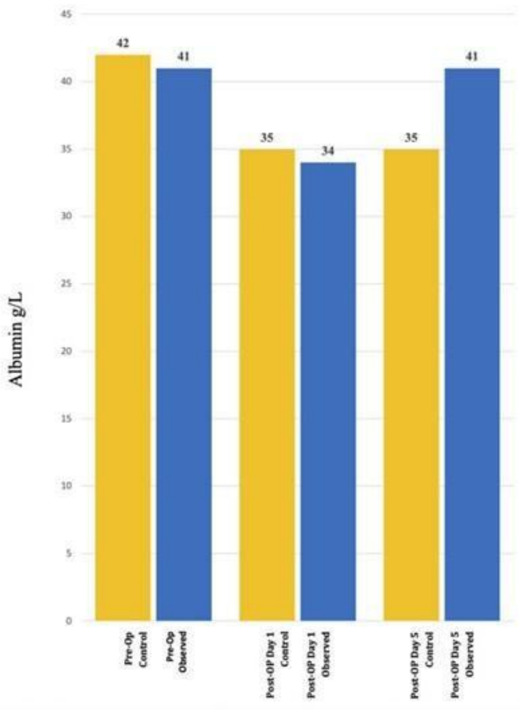

Figure 6: Comparison of pre-and post-operative albumin.

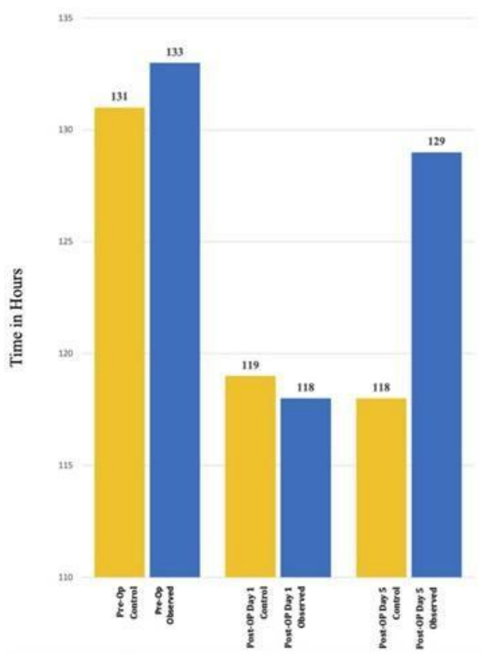

Figure 7: Comparison of pre-and post-operative Haemoglobin.

3.13. Integration of Wound Care with GI follow up and Nutritional Support

Wound healing after GI resection is an incredibly demanding process that heavily relies on nutrition that would otherwise be restricted due to GI resection surgery. Malnutrition and nutrient deficiencies are shown to lead to decrease in wound healing efficiency and delayed healing.

Nutrition deficits impair all stages of wound healing including inflammation, proliferation, and tissue remodeling. Recent studies show how the combination of nutritional support and wound-care procedures after GI surgeries achieve better outcomes. Furthermore, tailoring parenteral and enteral nutrition to patient demands is important in the efficiency of wound healing. Collaboration between nutritionists, physicians, and nurses is critical for recovery.

Physicians often monitor gut motility, absorption, and feeding regiments immediately post-operatively, while nurses monitor for infection and change dressings. The SONVI trial is also applicable here, as individuals who receive immunonutrition saw reduced infectious complications and therefore improved wound healing. In the SONVI trial, infectious complications occurred in only 10% of patients in the experimental cohort, compared to 30% in the control group presenting a 20% decrease in infection risk [51].

Individuals in another study monitored via ERAS protocol also saw reduced inflammatory markers with earlier enteric feeding, which was assumed to contribute to improved immune function and to better wound healing along with GI recovery [50].

Proper nutrition in post-operative patients is itself a predictor of wound healing and recovery in resection patients. Malnutrition can cause significant complications in surgical patients, and is not limited to GI resection patients. Some of the complications commonly seen from pre and post operative malnutrition include death, wound complications such as infection, sepsis, and prolonged hospital stays [52].

3.14. Gaps in Interdisciplinary Management

Although evidence and guidelines are present, several gaps remain in recovery management. Although ERAS protocol has been attributed to better recoveries, many patients under ERAS still do not reach targets for nutritional intake in the first few days after operations. Yeung et al. [53], 2017 indicated that protein intake remained inadequate in many patients, impacting their recovery significantly although other patients in the same cohort were more than capable of reaching nutritional goals [53,54].

Kawaguchi et al. [55], confirmed that early oral intake after GI cancer surgeries has increased over time but many patients who require additional PN nutritional supplementation receive doses far below the recommended guidelines [55].

Several factors play a role in nutrition after bowel resection surgeries. Some of the best early predictors of recovery include area of resection, total area removed, and early introduction of enteral nutrition after surgery. After review of the literature, it is also prevalent that many nutritional studies do not incorporate wound healing progress, leaving gaps in ensuring adequate or inadequate nutrition are affecting wound healing. Further study should incorporate extensive reporting on nutrition type and quantity projected alongside wound healing progress. Promising new research is also underway as more studies assessing immunonutrition are sure to follow.

3.15. Clinical Outcomes and Case-Based Evidence

Malnutrition prior to gastrointestinal surgeries is a predictor of poor post operative outcomes [56]. One such study analyzed the preoperative malnutrition risks of 943 patients undergoing gastrointestinal surgeries, including two-thirds of which involved bowel resections, 48 hours prior to surgery [56]. Malnutrition was found to be predictive of minor medical complications such as pneumonia, aspiration pneumonia, deep vein thrombosis, and urinary tract infection (Table 4) [56]. Higher preoperative malnutrition risks are tied to longer rates of length of hospital stays, higher 30-day and 60-day mortality rates [56]. This indicates that malnutrition reduces a patient's ability to recover from gastrointestinal resections and needs to be addressed prior to surgery for optimal recovery.

Another study found that malnutrition prior to surgery is a risk factor for recovery from gastrointestinal surgery, specifically for prolonged postoperative ileus (PPOI) [57]. Patients' preoperative nutritional status had a significant effect on the occurrence of PPOI.[57] PPOI can be predicted by the levels of albumin and hemoglobin levels.[57] These markers, used to indicate malnutrition, were identified as independent predictors for developing PPOI, as both albumin nd hemoglobin levels scored with a p-value of less than 0.001 [57,58]. In a separate study, levels of albumin of less than 3.5 g/dl had a higher rate of infection (28 patients) than patients with albumin g/dl levels higher than 3.5 (just 4 patients) [59].

Resection type can be tied to the malabsorption of specific nutrients such as in the duodenum which absorbs iron, calcium, fat-soluble vitamins, and vitamins B1 and B12 [2]. Without the duodenum, deficiencies in these nutrients may result. However, these resections do not always correlate with malabsorption as other areas of the intestine can acclimate by increasing its surface area to absorb those nutrients [60].

There are differences in postoperative nutritional impact when comparing total gastrectomy versus a subtotal gastrectomy [61]. Patients evaluated after surgery were found to have nutritional deficits, including anemia in over 90% of the individuals [61]. Total gastrectomy has a greater impact on nutrition compared to subtotal procedures which reinforces the need for early nutritional support (Table 4) [61]. Additionally, total gastrectomy patients were more affected regarding their sodium (p=0.05) and potassium levels (p = 0.02) which are statistically

Significant [61]. Proper sodium and potassium levels are needed to support wound healing [62]. Nutritional intervention, specifically early postoperative enteral nutrition (EPEN) was found to alleviate postoperative complications, including surgical site infections (SSIs) [63]. A retrospective study focused on 110 patients undergoing gastrointestinal tumor surgery with one group receiving EPEN while the others received conventional care [63]. This study found that EPEN may be associated with improvements in nutritional indicators, faster wound healing, and reduced surgical site infections in gastrointestinal tumor patients (Table 4) [63]. Wound healing time was significantly improved for those receiving EPEN treatment compared to the control group.[63]

Patients who received EPEN also had lower rates of surgical site infection (1.82%) as compared to the control group (17.02%) and had a lower incidence of wound bleeding (5.45% versus 9.09% of the control group).[63] While the incidence of surgical site infection for the EPEN group provides a statistical significant difference, the incidence of wound bleeding does not [63]. Regardless, treatment with EPEN does provide improved wound healing time and reduces the risk of surgical site infection [63].

A similar study also found that early enteral nutritional support significantly improved the outcomes for patients with gastrointestinal tumors undergoing surgery [64]. Patients receiving early enteral nutritional support were found to have a faster recovery [64]. This includes improved immune function and nutritional parameters after seven days post surgery as compared to patients who only received scoring p values of less than 0.05.[64] However, it was also found to increase the incidence of post surgical complications, noting that it may be due to the patient's condition, the added nutrients causing diarrhea, or the procedural risks such as infection, bleeding, and intestinal obstruction [64].

In another study, patients undergoing gastrointestinal surgery were split into two groups. The experimental group received comprehensive nutritional support, which included a combination of enteral and parenteral nutrition. The control group received only conventional comprehensive nutritional support (no EN or PN nutritional support) [65]. Wound infection rate and wound healing time were reported to be significantly lower for the experimental group which only had a 10% wound infection rate compared to the control group with an infection rate of 30%. Similarly, the experimental group recovered faster with an average of only 10.35 days as compared to the control group which required 14.42 days on average to recover (see Figure 8). The resulting evidence suggested that implementing comprehensive nutritional support programs greatly improves wound healing and reduces infections for those receiving gastrointestinal surgery (Table 4) [65].

Table 4: Summary of Studies.

Study	Design	Population	Intervention	Wound Outcomes
Ho et al. [56]	Prospective Cohort	943 patients for gastrointestinal surgery	Malnutrition risk assessment	Malnutrition risks predicted increased surgical complications and longer hospital stay
Weng et al. [63]	Retrospective cohort	110 patients undergoing surgery for gastrointestinal tumour	Early postoperative Eternal Nutrition {epen}	Faster wound healing times, lower rates of surgical sites infections, and improved nutritional markers
Akad et al. [61]	Prospective observational	295 patients undergoing total or subtotal gastrectomy	Comparison of nutritional outcomes post gastrectomy	Nutritional deficits observed postoperatively; anemia, sodium, and potassium irregularities common
Zhu et al. [56]	Retrospective cohort	310 patients with gastrointestinal cancer undergoing resection	Preoperative nutritional status assessment	Malnutrition associated with prolongrd postoperative ileus [PPOI], including lower markers for albumin and haemoglobin
Zhu et al. [65]	Retrospective	30 patients undergoing gastrointestinal surgery	Comprehensive nutritional support	Lower wound infection eate and lower wound hwaling time
Maji, et al. [66]	Retrospective	150 surgical patients	Evaluated for sermum albumin and wound related complications	Lower levels of serum albumin resulted in higher likelihood of developing wound related complications
Chen, et al. [64]	Retrospective	121 surgical patients with gastrointestinal tract tumours	Early enteral nutritional support	Improved nutritional status of patients and faster postoperative recovery

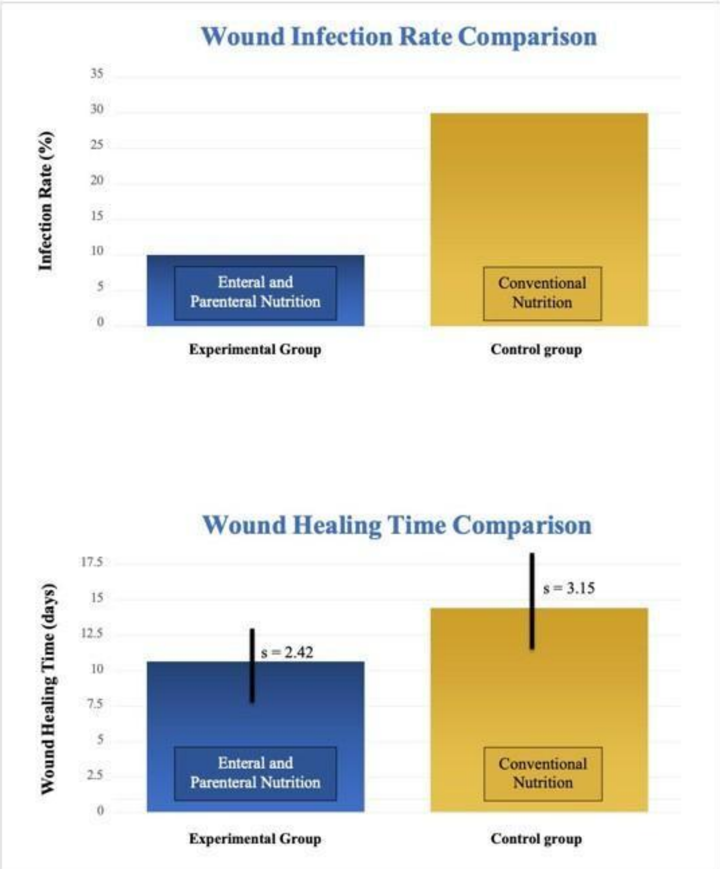

Figure 8: Nutrient Deficiencies and Prevalence Rates by Surgery Type.

3.16. Protocol Development and Clinical Recommendations

Evidence-based guidelines for nutritional screening and supplementation post-GI surgery. Patients undergoing postoperative gastrointestinal (Gl) surgery after various intestinal resections, are monitored for malabsorption syndrome and malnutrition. This is based on factors that cause patient health to deteriorate including deficiencies in vitamins and vital nutrients. Malabsorption syndrome, due to the loss of surface area in the GI tract, interferes with an individual's normal digestive function and decreases absorption during the digestive phase [66]. Nutritional screening and supplementation improves patient outcomes and sustains overall health when clinicians monitor early for post-operative GI intestinal issues. Nutritional screening checks for post operative conditions such as malnutrition, measures serum albumin levels, inflammatory rates, and the use of nutritional care such as enteral or parenteral interventions [67]. Nutritional screening entails clinicians to prioritize risk factors for a patient such as reduced food intake, low serum albumin levels, low BMI and weight loss, as depicted in Figure 2 [34]. Following nutritional screening, providing adequate nutrition through routes of accessibility to a patient entails food intake either orally, through a feeding tube (enteral) or through the bloodstream (parenteral) as presented in Figures 1 and 2. Post operatively, early oral feeding is a safe and preferred method of nutrition intake as it bears minimal risk, but if oral feeding is insufficient, enteral (tube feeding) and parenteral (food intake via bloodstream) nutrition is suggested [34].

3.17. Optimal Wound Care Protocols Tailored to Malabsorptive Patients

Patients that undergo GI surgery for various resections of the intestinal tract tend to experience nutrition deficiencies and malabsorptive issues which diminishes wound healing responses in the recovery stages. Wound healing protocols allow malabsorptive patients to cope with post operative stress induced by surgical interventions through gastrointestinal support techniques. Adequate nutritional intake provides energy and a strong metabolic response which are both vital to wound healing. Early enteral feeding combined with parenteral nutrition, provideminerals and nutrients to assist in preserving intestinal function and reducing infection risks [65]. Macronutrients are proteins, fats, amino acids and micronutrients such as minerals and essential vitamins (A, B12, C, E, K) that are important in cellular repair mechanisms that promote wound healing in postoperative patients. Collagen synthesis and tissue repair are enhanced in the body through nutritional support, allowing for faster wound healing. Essential nutrients such as vitamin C and zinc play a key role in this process, as illustrated in Figure 1 [65]. Collagen generation relies on amino acids, mainly arginine and glutamine, that indirectly produce the collagen precursor, proline [68]. Malabsorptive patients, post GI surgery, are known to have a slower wound healing period, where collagen production is reduced. Vitamin C is an important cofactor in the production of collagen which helps endothelial vasodilation and lowers inflammation. This collectively improves wound healing and patient immunity [69].

3.18. Recommendations for Interdisciplinary Coordination and Long-Term Follow-Up.

As patients seek interdisciplinary coordination post GI surgery, a combined effort of different clinicians in their respective fields come together to provide the best treatment plans and long term follow up assistance to best cater to the patients needs. Meeting with the patient post GI surgery may strengthen the patient profile as clinicians check for infection rates, post GI surgery symptoms, as well as monitoring nutritional uptake. Home parenteral support (HPS) and intestinal rehabilitation programs, common methods of patient follow up as seen in Figure 2, are taken up by multidisciplinary teams which include a dietician, registered nurse, pharmacist and a clinician trained in clinical nutrition [70]. Physicians who manage postoperative patients are trained to provide follow up care through patient education on symptoms and long term follow up plans where patients can maximize on the best care possible. In one study, patients with a high ileostomy range who showed signs of dehydration received patient-centered diet plans to best accommodate their needs as well as fluid replacement therapy. Both of these being managed by dietitians and stoma nurses [71].

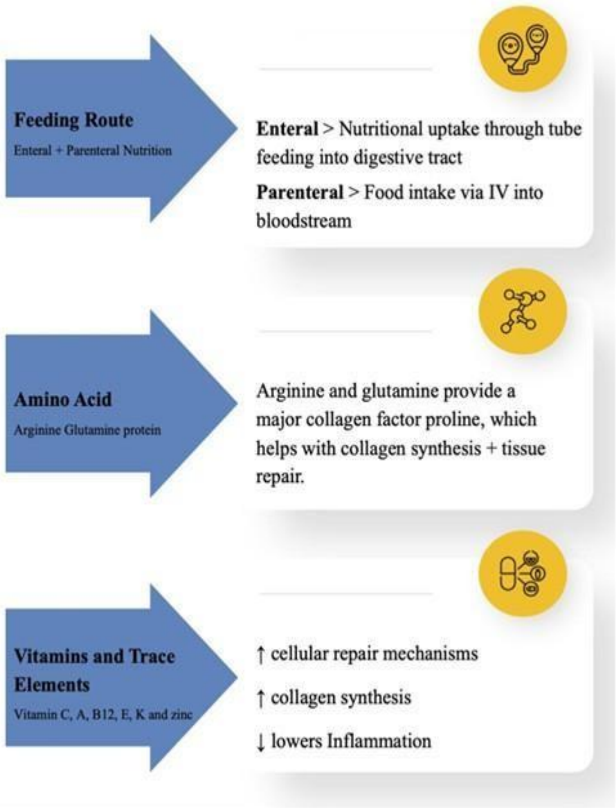

Figure 9: Nutritional Interventions to Enhance Wound Case via Feeding Routes, Amino Acid Supplementation, Vitamins, and Trace Elements.

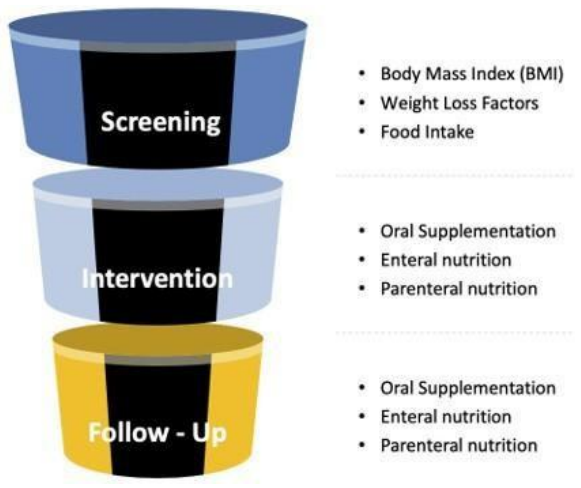

Figure 10: Directional Flow of Patient Encounter Post- GI Surgery.

3.19. Include Discussion of Barriers to Implementation (E.G., Resource Limitations, Lack of Training).

Barriers in the healthcare field during post operative GI surgery have been vastly discussed among many different interdisciplinary teams where each role of a physician is challenged. Each and every role in a healthcare setting during post operative care changes as roles are reversed and knowledge gaps are created. Staff turnover in which physicians are changed in healthcare results in a loss of knowledge and overarching experience that may impact

the rest of the team [72]. Lack of knowledge and understanding of certain aspects of care post operatively among surgeons may be due to the rapid staff turnover in healthcare as well as deficits in clinical care where patients are not understood. Clinicians may experience challenges in understanding and administering nutritional support. This is especially due to a lack of awareness of postoperative malnourishment and its clinical relevance [73].

4. Conclusion

After gastrointestinal surgery, some patients develop post operative malabsorption which slows down the body's ability to heal wounds, but is generally reversible with proper management and care. Numerous studies show that when patients lack important nutrients such as protein, amino acids and vitamins (A, B_{12}, C, D, E, K), or minerals such as zinc or iron, wounds heal slower. These nutrients are needed to synthesize collagen, build new tissue and form new blood vessels which are all steps to healing faster. Starting nutritional support early instead of waiting or relying on IV feeding helps patients recover faster, reduces infection risk and shortens hospital stay. This shows how treating malabsorption is an important part of overall recovery and should be seen as a primary treatment goal, rather than just an inevitable consequence of surgery.

For smooth recovery after gastrointestinal surgery, patient care should be well coordinated and consistent across different specialties. Nutrition support, wound care and GI follow up should work together and not in isolation. Using Enhanced Recovery After Surgery (ERAS) pathways and routine nutritional checks such as albumin, hemoglobin, BMI and recent weight loss helps identify patients at risk earlier on. Starting enteral feeding within 24 to 48 hours, meeting daily protein goal of 1.2 to 2 grams per kilogram, and structured micronutrient replacement are all proven strategies to support the healing process. When surgeons, nursing teams and dietitians work together, maintain close communication and adjust nutrition plans as needed, patients heal faster, avoid infection and spend less time in hospital. The team work also helps educate patients and their families so they can continue proper nutrition and wound care after discharge.

Most of the current research is based on observational or retrospective studies, which makes it harder to draw conclusions. The studies also vary in number of patients, types, amounts and timing of nutrition used. Socioeconomic disparities, available hospital resources and surgical techniques also differ, making it hard to apply the results to all settings. Only a few studies have looked at how nutrition affects wound healing and there is not much long term data yet. Hence, there is a clear need for better and more consistent ways to measure patient outcomes, and future studies that follow patients for longer periods of time. Future research should focus on larger and well designed clinical studies to see how different nutrition approaches like starting tube feeding early or combining tube and IV feeding can improve wound healing after surgery. It would also be great to have long term patient records that track nutrition levels, healing progress and hospital readmission to get a better picture of what works. Hospitals can improve care by using the same screening tools and treatment steps across surgical teams so that nutrition is managed more consistently.

Moving forward, researchers should run larger, more planned clinical trials to see how different nutrition approaches like starting tube feeding early, or combining tube and IV feeding work for wound healing after surgery. It would be great to have long term patient records that track nutrition levels, healing progress and hospital readmissions, to get a better idea of what works.

Hospitals could improve care by using the same screening tools and treatment steps across all surgical teams, so nutrition is managed more consistently. Surgeons, dietitians and wound care nurses working together can give patients better and more continuous care during recovery. Researchers should also look at how realistic and affordable these nutrition programs are, especially in resource poor hospitals. Finally, giving doctors and nurses more hands-on training on nutrition and recovery could fill the knowledge gaps, make care more uniform and lead to better outcomes for patients.

5. Conflict of Interest Statement

The authors (Zohair Siraj, Syed Haroon Mohammed, Holly Timmerman, Montana Ricci, Colter Romo, Cordell Farmer, Maheen Zaidi, Hannah Bolleddu, Aisha Azghar, Pasha Bazzal) of this manuscript declare that they have no conflicts of interest that are directly or indirectly related to the work submitted for publication. Specifically:

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