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Review

Dietary Considerations and Nutritional Strategies to Enhance Recovery After Cardiac Surgery: A Comprehensive Review

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Abstract

The metabolic and inflammatory burden of cardiac surgery results in increased protein catabolism, elevated energy expenditure and thereby a consequent increased risk of postoperative complications. Therefore, it is imperative to optimise nutritional status preoperatively and postoperatively to ameliorate these effects on wound healing, immune function, and recovery of the myocardium, in addition to other clinical outcomes. Despite its benefits, structured perioperative nutritional care is rarely undertaken. In this narrative review, we will summarise contemporary literature (2017–2026) and international guideline recommendations to outline phase-specific nutritional strategies for patients undergoing cardiac surgery. In the early postoperative period, early initiation of enteral nutrition, adequate protein provision (1.2–2.0 g/kg/day), and careful fluid and glycaemic management are critical to attenuate catabolic stress and reduce complications. During hospital recovery and discharge to home, emphasis should shift towards caloric adequacy, micronutrient optimisation—particularly vitamins C and D, zinc, and iron—and management of medication-related gastrointestinal effects. In the long-term phase, adoption of cardioprotective dietary patterns such as the Mediterranean and Dietary Approaches to Stop Hypertension (DASH) diets supports secondary prevention and cardiovascular risk reduction. Elderly patients who are sarcopenic, individuals with diabetes mellitus or chronic kidney disease (CKD), overweight individuals and people on anticoagulation warrant special consideration. Integrating nutritional assessment and intervention into Enhanced Recovery After Cardiac Surgery (ERACS) pathways may help improve recovery trajectories and reduce morbidity. Further high-quality research should be conducted to define procedure-specific and individualised nutritional protocols in the cardiac surgical population.

Keywords: cardiac surgical procedures; perioperative care; nutrition therapy; protein intake; DASH diet

1. Introduction

1.1 Global Burden of Cardiac Surgery and Patient Outcomes

Globally, cardiovascular diseases remain the leading cause of death, resulting in more than two million open-heart surgeries performed each year. Despite many developments in surgical techniques, anaesthesia, and perioperative care for the patients before and after heart operations, cardiac surgery is still a major cause of the physical stress of patients. Physical stress is normally associated with a longer time period for recovery, higher complication rates after surgery, and a higher mortality rate [1].

Postoperative outcomes in cardiac surgery patients are affected by many different factors, including the nutritional status of a patient before the operation, the complexity of the surgical procedure, and the amount of time the patient was on cardiopulmonary bypass (CPB) during surgery. It is worth mentioning that it has been estimated that approximately 25–50% of patients undergoing cardiac surgery are significantly affected by malnutrition [2].

Malnutrition in the cardiac surgery patient population is strongly associated with increased morbidity and mortality, and is tied directly to a patient's difficulty bouncing back from heart surgery, developing infectious processes post-surgery, prolonged hospitalisation and an increased risk of readmission. This is just one reason why the prognostic nutritional index (PNI) is a worthy tool for assessing the nutritional status of a heart patient prior to surgery. A patient with a low PNI score will have a higher incidence of postoperative complications, including infections, delayed wound healing, and prolonged mechanical ventilation, than a patient with a higher PNI score [3].

1.2 Role of Nutrition in Surgical Recovery and Prevention of Complications

Optimal recovery from cardiac surgery requires an adequate amount of nutrition. Adequate protein and caloric intake aid in the healing process of the median sternotomy wound, support the sufficient function of the immune system, decrease the likelihood of infection, and prevent excessive lean mass loss during the catabolic stress period. Likewise, adequate nutritional intake will provide proper metabolic substrates needed for myocardial repair and functional recovery [4].

Patients who undergo cardiac surgery experience dramatic metabolic changes, including a hypermetabolic and hypercatabolic state. They will have an increased caloric requirement due to increased energy expenditure and increased protein breakdown. Additionally, the altered use of substrates will contribute to the development of insulin resistance. If a patient's catabolic state is not addressed with adequate nutritional interventions, they are at risk for developing skeletal muscle loss, poor wound healing, and experiencing infectious complications and adverse postoperative outcomes [4].

There is a 0.5–5% incidence of either superficial or deep sternal infections or mediastinitis following a median sternotomy. Notably, mortality rates associated with sternal wound complications range from 7 to 80%. A malnourished patient is more prone to these complications due to decreased collagen synthesis, decreased immune function, increased hypoxia secondary to anaemia, and prolonged inflammatory response. Current evidence indicates that with appropriate perioperative nutrition, there is an approximately 30–40% reduction in postoperative infectious complications in surgical patients [5,6].

1.3 Gaps in Current Guidelines and Rationale for This Review

Despite current evidence regarding the influence of nutrition on postoperative outcomes, most patients who undergo cardiac surgical procedures receive inadequately organised, evidence-based nutritional support. While both the European Society for Clinical Nutrition and Metabolism (ESPEN) and the American Society for Parenteral and Enteral Nutrition (ASPEN) provide practical guidance on perioperative nutrition, neither presents tailored recommendations by type of procedure that address the unique metabolic demands imposed by surgical procedures on cardiac surgery patients.

To date, there are no full, protocolized nutritional guidelines able to properly encompass the challenges of the metabolic responses surrounding cardiac surgery. Enhanced Recovery After Surgery (ERAS) programmes are defined, structured, multimodal, perioperative care pathways designed to reduce the surgical stress, enable rapid recovery and improve outcomes across all operation types. In 2019, the principles of ERAS were adapted for patients undergoing cardiac procedures, producing Enhanced Recovery After Cardiac Surgery (ERACS) guidelines, offering procedure-specific advice encompassing the physiologic and inflammatory responses of patients undergoing cardiac surgery. The 2019 ERACS guidelines have introduced targeted perioperative nutritional management strategies; however, there is insufficient detail regarding postoperative nutritional protocols, resulting in a lack of standardisation across institutions [7]. Updates released in the most recent version of the ESPEN guideline on clinical nutrition in surgery (2025 update) provide graded, evidence-based recommendations given to all surgical populations, including screening and treatment for nutritional risk, multimodal peri-operative care pathways, minimising fasts, and resuming early oral or enteral nutrition as soon as clinically feasible. However, even these global recommendations indicate the need for more nuanced guidance tailored to specific procedures, particularly tailored to the unique metabolic and inflammatory characteristics of cardiac surgery patients [8].

Suboptimal nutritional adherence remains prevalent in this patient population, and current literature has demonstrated that only approximately 7% of all patients who undergo cardiac surgical procedures receive preoperative nutritional optimisation. Moreover, only half of all patients achieve recommended caloric and protein intake during the first week after surgery, even with ERAS care structures in place [7].

Nutritional practices are inconsistent across cardiac intensive care unit (CICU) settings, and many centres do not provide integrated and dedicated nutritional support services for this very high-risk patient population. There is still a need for further research regarding the timing of nutritional intervention, the ideal macronutrient content for cardiac patients, the utility of immunonutrition, and specialised nutritional support for vulnerable sub-populations, such as elderly patients with sarcopenia, patients with chronic kidney disease (CKD), and patients receiving long-term anticoagulation therapy [9].

1.4 Aim and Scope of the Article

The primary objective of this review is to provide a comprehensive overview of the available literature pertinent to the nutritional management of individuals undergoing cardiac surgical procedures, specifically, the physiologic and metabolic changes impacting nutritional requirements throughout the perioperative continuum (i.e., intensive care unit, and hospital).

Furthermore, we will discuss notable situations which represent challenges for patients with special needs (e.g., comorbidities) while emphasising the collaborative nature of interdisciplinary care teams in advancing nutritional care in the perioperative period. The literature base for this review includes clinical trials, systematic reviews and/or meta-analyses, as well as internationally accepted clinical guidelines to derive specific strategies to enhance the nutritional support provided to individuals undergoing cardiac surgery and thereby improve postoperative outcomes.

A directed, systematic search through both PubMed and ScienceDirect during the period of January 2017 to March 2026 was utilised to locate literature to include in this review. The type of literature included clinical practice guidelines (CPGs), systematic reviews and/or meta-analyses, and randomised controlled trials regarding perioperative and/or postoperative nutrition in adults who have undergone cardiac surgery. Additionally, CPGs from ESPEN, ASPEN, ERACS, and the American Heart Association (AHA) were included in this synthesis of findings. The resulting compilation of literature was refined based on the clinical pertinence of the publications to contemporary cardiac surgery practice.

2. Pathophysiological Changes and Nutritional Impact After Cardiac Surgery

2.1 Metabolic Stress Response to Surgery

Following cardiac surgery, there are profound changes in the neuroendocrine and hormonal milieu of the body, resulting in a situation of hypermetabolism. The quantity of energy that the body requires to function when resting, i.e., resting energy expenditure (REE) will be greater than prior to surgery (of the order of 20–30% above baseline), and this elevation may persist for several days to several weeks post-surgery; this elevation is that which corresponds to the biphasic metabolic response to surgical stress as described by Şimşek [10]. In this biphasic response, there is an acute (2–3 day) "ebb" phase in which metabolic rate drops transiently through lowered cardiac output and a long (>2–3 day) "flow" phase in which the increased energy needs due to hypermetabolism and increased demand for oxygen and upregulated protein catabolism for energy needs are sustained [10].

The most important determinants of the magnitude of the metabolic stress are the complexity of the surgery and time spent on CPB, as well as postoperative complications. With this hypercatabolism, breakdown of skeletal muscle protein will exceed synthesis, and the patient who does go on to receive appropriate nutritional support after surgery could "lose" an estimated 20–30 g of nitrogen per day, reflecting muscle protein breakdown [11].

Extended periods of immobility will also contribute to muscle wasting. There is evidence to suggest that a 10-day period of immobility post-surgery could lead to an up to 15% decrease in total body mass. The amino acids released by muscle protein breakdown to fuel energy requirements will be used for gluconeogenesis in the liver and to produce acute-phase proteins, depleting muscle stores and nutrients in the periphery.

2.2 Inflammatory Response and Oxidative Stress

Cardiac surgery patients experience a systemic inflammatory response syndrome (SIRS) secondary to CPB and surgical trauma to the sternum. This response is characterised by the release of pro-inflammatory cytokines, including interleukin-6 (IL-6), tumour necrosis factor-alpha (TNF-α), and interleukin-1β (IL-1β) [11,12,13].

The inflammatory process is important for the repair of tissue and healing of wounds, but excessive or dysregulated inflammation leads to postoperative complications such as atrial fibrillation (AF), acute kidney injury (AKI), and prolonged ventilatory support necessitating longer periods of intubation and mechanical ventilation. Excessive inflammatory response leads to the production of a high amount of reactive oxygen species (ROS), which may often exceed the endogenous antioxidant capacity of the body, leading to oxidative stress and cellular injury [11,14].

Nutritional status is adversely affected by inflammation through a number of interrelated pathways. Pro-inflammatory cytokines act directly on hypothalamic centres regulating appetite, causing anorexia and trophic effects that result in catabolism of skeletal muscle by activating ubiquitin-proteasome pathways. This process promotes preferential hepatic synthesis of acute-phase proteins at the expense of albumin and alters substrate metabolism toward increased oxidation of lipids and proteins [14]. Additionally, the augmented inflammatory and oxidative stress response depletes vitamins and minerals, especially antioxidant vitamins, such as vitamins C and E and trace elements, such as zinc and selenium, which are essentially required for normal endogenous antioxidant enzyme function [13,14].

2.3 Fluid Shifts and Electrolyte Disturbances

Homeostatic changes caused by CPB can lead to extreme amounts of capillary leakage, which in turn causes a redistribution of fluid and an increase in total body water of up to 30%. Because the effective intravascular volume is reduced significantly due to the marked capillary leakage, this reduction results in neurohormonal pathway activation, including but not limited to the renin-angiotensin-aldosterone system (RAAS) and antidiuretic hormone (ADH) secretion, creating difficulties with fluid management in the postoperative period [14,15].

Approximately 50–60% of patients undergoing cardiac surgery develop postoperative fluid overload. Defined as a >5% increase in body weight from baseline, this is independently associated with worse outcomes such as prolonged mechanical ventilation, longerintensive care unit (ICU) stays, increased rates of AF, and increased mortality rates [15].

Electrolyte derangements occur often upon admission to the ICU; however, emerging evidence suggests that increased serum potassium and magnesium levels are associated with an increased risk of postoperative AF [15].

The above suggests that routine or systematic supplementation of these electrolytes may be unnecessary or even deleterious, and that electrolyte management should be guided by regular quantitative assessment and corrected individually rather than added to intravenous (IV) fluids indiscriminately [16].

2.4 Gastrointestinal Tolerance and Dysfunction

There are multiple reasons behind gastrointestinal problems after cardiac surgery, and they are commonly due to the combination of general anaesthesia, opioid medication, stimulated sympathetic nervous system, low blood flow to the intestines (visceral hypoperfusion) while on CPB and the mechanical forces of positive pressure ventilation. Consequently, many patients will experience gastrointestinal intolerance in the early postoperative period, with nausea, delayed gastric emptying, and reduced oral intake being the most common manifestations [16,17,18].

Complications of the gastrointestinal system include paralytic ileus, one of the most serious complications for patients after surgery. About 30–35% of patients have some gastrointestinal morbidity due to paralytic ileus, and the incidence is very broad, varying from 0.3% to 5.5%. However, there is also an increased incidence of severe gastrointestinal complications after cardiac surgery, which are associated with high morbidity and mortality rates in the presence of other major complications, such as bowel ischemia, sepsis or multiorgan dysfunction. Information regarding mortality rates in patients with severe gastrointestinal problems is very different, with mortality rates varying between 0.3–87% depending on the study design and patient samples or cases selected for the trials [17].

Post-extubation dysphagia occurring in approximately 3–67% of patients after cardiac surgery is another example of a common complication in these patients. Directly influenced by the duration of endotracheal intubation and the risk factors specific to that patient, each patient's chance of experiencing dysphagia can significantly differ. Assessments of swallowing ability have shown that as many as 94% of patients will have unsafe swallowing, including aspiration in 29% of patients, among whom 53% experienced silent aspiration.

The previously mentioned risk factors that have been identified to predict which patients may be more prone to having post-extubation dysphagia include intubation longer than 48 hours (10-fold increase in risk), advanced age, New York Heart Association (NYHA) functional classes III–IV, acquisition of more than 110 transesophageal echocardiography (TEE) images, and the use of large-size (≥8.0 mm) endotracheal tubes. Compared with non-aspirators, patients with aspiration also experience delays in resuming oral intake (approximately 85 hours longer), have significantly increased health costs (estimated to be additional USD 49,372 per patient), have 43% longer hospital stays and face increased risks of pneumonia, reintubation, and mortality [19].

2.5 Implications for Energy and Nutrient Requirements

During the postoperative period, nutritional requirements increase substantially in patients undergoing cardiac surgery. Their need arises from a combination of hypermetabolism, protein catabolism, systemic inflammation, and gastrointestinal dysfunction. Normally, patients who have had heart surgery require 25–30 kcal/kg/day, but patients who require prolonged mechanical ventilation for weeks or months, or patients who have developed other complications postoperatively, tend to require 30–35 kcal/kg/day [5].

Very high protein needs exist when compared to the healthy adult population, with recommended intakes ranging from 1.2 to 2.0 g/kg/day, as opposed to approximately 0.8 g/kg/day in the general population. Adequate protein intake is essential to support wound healing, preserve lean body mass, and facilitate the synthesis of acute-phase proteins during the stress response to surgical trauma [20].

The energy and protein levels for patients change while in recovery, as described, so adjustments to those levels should be made based on how fast they heal and how healthy they are after surgery [21].

Nutritional requirements of micronutrients are often increased in the perioperative setting. The role of vitamin C in this context of collagen production is to hydroxylate proline and lysine. This makes an abundance of vitamin C during healing indispensable. The amount required during recovery may be as much as twice that of the adult normal. Vitamin D deficiency is very common, affecting 50% to 75% of cardiac surgery patients and affecting calcium homeostasis and bone metabolism [20].

Zinc is a cofactor for over 300 enzymes involved in protein synthesis, immune regulation and cellular repair. The status of zinc affects many steps of the healing process, including modulation of inflammation, migration of keratinocytes, proliferation of fibroblasts, production of collagens and remodelling of the extracellular matrix. Both experimental and mechanistic studies elucidate the need for zinc in preserving epithelial integrity and promoting correct immune responses. Observational studies have shown that zinc deficiency affects wound healing [22]; however, evidence from clinical trials regarding the effect of zinc deficiency and routine supplementation on postoperative wound healing outcomes is mixed. As documented by Bechara et al. [23], certain clinical trials showed no consistent or significant correlation between wound healing and zinc status, particularly in patients without confirmed deficiency. Thus, while zinc is biologically necessary for tissue healing, supplementation should be individually based on documented deficiency and/or other specific clinical indications; therefore, routine supplementation should not be performed. The pathophysiological mechanisms associated with cardiac surgery and increased nutritional needs are summarised in Fig. 1.

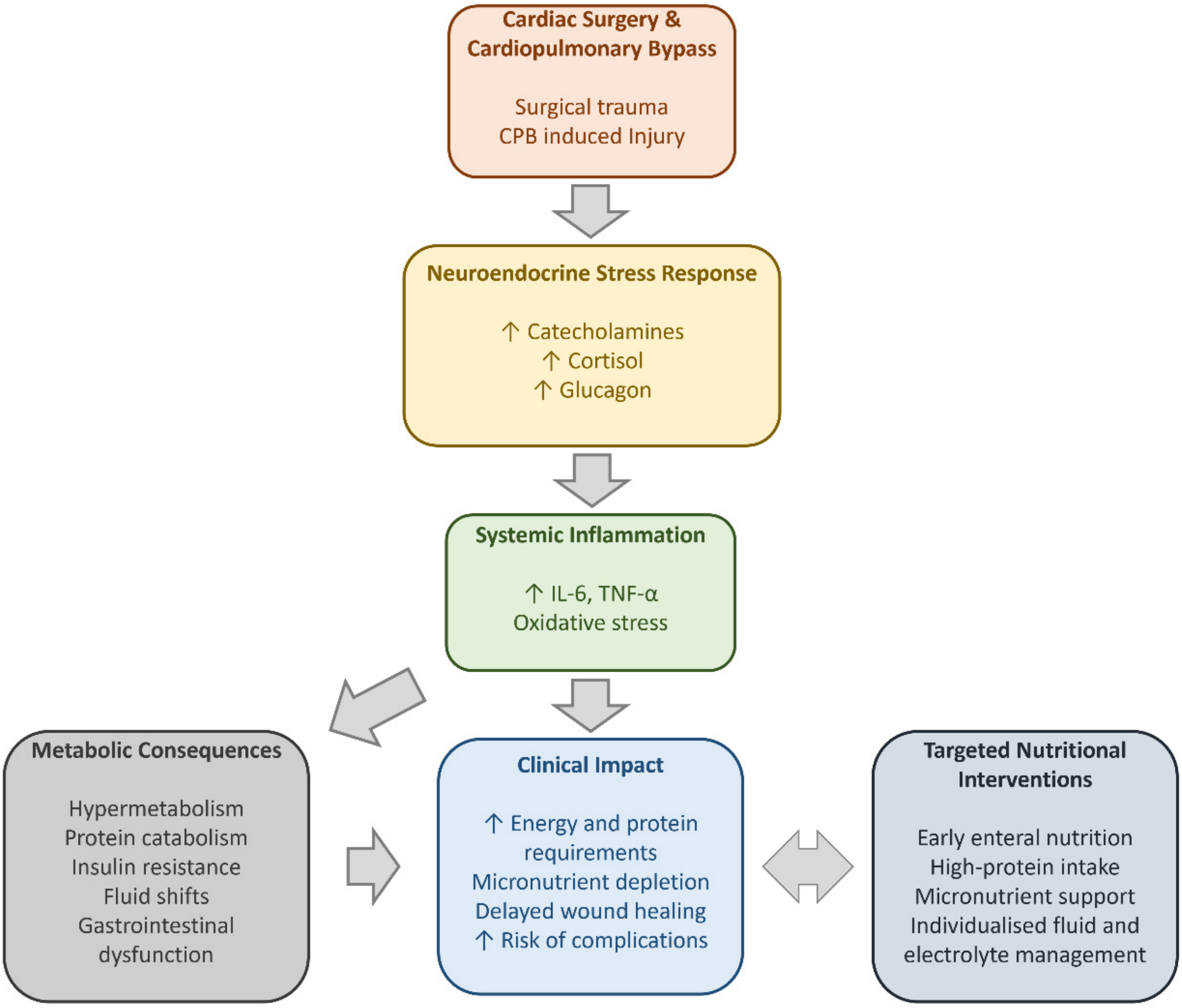

Fig. 1. Pathophysiological mechanisms driving increased nutritional requirements after cardiac surgery. Cardiac surgery and cardiopulmonary bypass trigger a neuroendocrine stress response and systemic inflammation, resulting in hypermetabolism, protein catabolism, insulin resistance, fluid shifts, and gastrointestinal dysfunction. These processes lead to increased energy and protein demands, micronutrient depletion, impaired wound healing, and a higher risk of postoperative complications. Targeted nutritional interventions aim to counteract these effects and support recovery. Created by the authors using Microsoft PowerPoint 2021 (Microsoft Corp., Redmond, WA, USA). CPB, cardiopulmonary bypass; IL-6, interleukin-6; TNF-α, tumour necrosis factor-alpha.

3. Postoperative Dietary Concerns

3.1 Early Postoperative Phase (ICU to Step-Down Unit)

3.1.1 Timing of Initiating Oral and Enteral Feeding

The integration of early enteral nutrition (EN) for patients following cardiac surgery is part of protocols for enhanced recovery after surgery. As such, it is recommended that EN begin within 24–48 hours following surgery. This concurs with the 2025 ESPEN guidelines on clinical nutrition in surgery that encourage the re-establishment of early oral intake when possible, with commencement of nutritional care for those at risk of under-nourishment and incorporation into enhanced recovery programmes as part of integrated peri-operative care pathways [8]. Early EN has many other physiological and clinical benefits: it helps prevent degeneration and loss of the gut barrier and reduces bacterial translocation, both lowering patients' risk of developing an infection [24].

Furthermore, early EN helps to ameliorate the postoperative inflammatory response, thereby preventing further degrees of cumulative under-nutrition, which can be seen in critically ill patients. A large retrospective study involving more than 3500 cardiac surgery patients admitted to the ICU demonstrated that enteral feeding initiated within 24 hours was associated with a significantly lower incidence of persistent inflammation, immunosuppression, and catabolism syndrome (PICS), a reduction in hospital length of stay by approximately 2.2 days, and decreased rates of postoperative infections [25].

Despite these advantages, there are still numerous barriers to implementing early EN. A study has shown that close to 95% of patients are safe to be started on oral intake on the first postoperative day, yet nausea, dysphagia, lack of appetite and fear of aspiration are all reasons that preclude oral intake for many patients [5].

Patients unable to ingest their nutritional needs orally should receive appropriate, timely EN via either nasogastric or post-pyloric feeding tubes. Parenteral nutrition should only be started if EN is contraindicated or if caloric requirements cannot be met orally/enterally within 7 days postoperatively [26].

3.1.2 Managing Nausea, Dysphagia, and Reduced Appetite

Patients have 25–30% risk of postoperative nausea and vomiting after cardiac surgery, which may impede their ability to get adequate nutrition. The ERAS protocols indicate that most studies incorporated some form of antiemetic prophylaxis using multimodal regimens that include 5-hydroxytryptamine-3 (5-HT$_3$) receptor antagonists, dexamethasone, and prokinetic agents such as metoclopramide. In addition to pharmacological management, non-pharmacological strategies are recommended, including the provision of small, frequent meals, offering cold or room-temperature foods that are often better tolerated, minimising exposure to strong odours, and allowing sufficient time for meals to reduce feeding-related discomfort [27].

Assessment of dysphagia following extubation should follow a systematic and standardised clinical approach. Clinicians are encouraged to apply validated screening tools, such as the Yale Swallow Protocol, to all patients after extubation, with heightened vigilance for high-risk individuals, including those with prolonged mechanical ventilation, advanced age, or a history of cerebrovascular disease [28].

For patients identified with swallowing impairment, referral for suitable specialist evaluation is therefore recommended. Dietary texture modification should be guided by formal swallowing assessment and accompanied by compensatory strategies, such as the chin-tuck manoeuvre, alternating between liquids and solids, and close monitoring during feeding, in order to minimise the risk of aspiration and to ensure safe nutritional intake [28].

3.1.3 Protein-Energy Requirements for Healing and Muscle Preservation

Achieving enough protein and energy consumption is particularly difficult in the early postoperative period. Recent studies indicate that mean caloric intake during postoperative days 2 to 4 is approximately 1088 kcal/day, with average protein intake of about 0.8 g/kg/day—substantially below the recommended targets of 25–30 kcal/kg/day and 1.2–2.0 g/kg/day, respectively. Even within established ERAS pathways, only approximately 41% of patients undergoing cardiac surgery achieve at least 70% of their estimated nutritional requirements [5]. Although peak catabolic stress occurs during the early postoperative period, adequate protein provision (≥1.2 g/kg/day) should be maintained throughout the intermediate recovery and rehabilitation phases to support muscle rebuilding and functional recovery, particularly in elderly or sarcopenic patients.

During the early recovery phase, oral nutritional supplements (ONS) are important tools for addressing the nutritional deficit of patients. By the end of postoperative day 2 (POD2), on average, high-protein and highly caloric ONS contribute approximately 35–38% of total calories and total protein consumed [9]. Unfortunately, compliance with ONS has been shown to decline on POD3 and POD4 [9], which decreases the overall effectiveness of these products as nutritional support during the period of greatest catabolic stress post-operatively.

In order to promote compliance with ONS, several methods have been shown to improve adherence, including giving multiple flavour options, giving ONS between meals (instead of with a meal), serving ONS cold rather than at room temperature, and having nursing staff involved in encouraging patients to take ONS. Patients who are unable to meet their energy and protein needs with oral intakes (including the ONS) should be referred for enteral tube feeding to prevent continued deficits of protein and calories [9].

3.1.4 Fluid Balance and Sodium Restriction

Fluid management is a component of patients' nutrition after cardiac surgery, because of its complexity. Thus, managing how much fluid is taken after heart surgery becomes an analytical approach that guides patients to maintain adequate cardiac output and organ perfusion while avoiding fluid overload. Recent evidence suggests that rather than using traditional liberal methods of allowing a patient to drink freely, a more restrictive strategy limiting how much fluid is available for the patient to drink—aimed at achieving euvolaemia rather than a positive fluid balance—will result in fewer complications after surgery [29].

Patients with heart failure usually have a fluid allowance of 1.5–2.0 litres a day on average. More recently, it has become appreciated that a strictly restricted fluid allowance is not universally satisfactory in assisting patients; therefore, fluids should be administered to patients with respect to: (i) their hemodynamic status, (ii) the sodium content of their serum, (iii) the extent of fluid congestion, and (iv) overall clinical health condition. The current recommendation for patients with heart failure is to limit sodium intake to 2–3 g/day in most cases [30].

The current international heart failure guidelines indicate that routine restrictions on fluid intake should not be applied to all patients but rather should be tailored to the patient based upon: (i) the severity of their symptoms, (ii) their level of congestion, and (iii) their laboratory biochemical values [31,32]. In patients with preserved or mildly reduced functional capacity (NYHA class I–II) and no clinical evidence of fluid overload or hyponatraemia, liberal fluid intake within physiological limits (approximately 15–30 mL/kg/day) is generally acceptable, provided careful monitoring of body weight and volume status is maintained [31].

In contrast, most patients with symptomatic heart failure (NYHA class III) and clinical signs of congestion may benefit from mild fluid restrictions (1.5–2.0 litres/day), particularly when fluid limitations are combined with sodium restrictions (≤2 grams/day) [33]. For patients with advanced heart failure (NYHA class IV), especially in the presence of persistent congestion, dilutional hyponatraemia, or recurrent hospitalisations, more structured fluid management—including stricter intake monitoring, daily weight surveillance, and close adjustment of diuretic therapy—is recommended [31]. In selected cases, individualised targets below 1.5 litres per day may be considered, guided by renal function, serum sodium concentration, and hemodynamic stability [32].

The European Society of Cardiology (ESC), the American Heart Association (AHA), American College of Cardiology (ACC), and Heart Failure Society of America (HFSA) all emphasise in their guidelines that fluid restriction should not be considered a universal method for all patients based solely on NYHA class and without regard to specific objective markers of congestion, natriuretic peptide levels, renal function, and overall clinical context [31,32,34]. Overly aggressive attempts to reduce fluid intake in patients who are haemodynamically stable could cause excessive dehydration, renal failure, and hypotension, particularly in the early postoperative period when the patient is recovering from surgery and needs adequate volume, as well as optimal antecedent volume.

For patients with moderate to severe symptoms of heart failure, generally speaking, sodium intake has been restricted to ≤2 g/day. However, several studies have questioned whether this standard practice of aggressively restricting sodium to 2 g/day for patients with heart failure produces consistent clinical benefits versus being counterproductive, particularly among individuals receiving aggressive management with diuretics [35].

3.1.5 Blood Glucose Control

Even without prior diabetic status, hyperglycaemia in the perioperative setting is linked to an increased incidence of sternal wound infections, cardiovascular adverse effects, and mortality following cardiac surgery. Evidence from the Portland Diabetic Project demonstrated that maintaining blood glucose levels below 150 mg/dL using continuous insulin infusion reduced mortality by 57% and sternal wound infection rates by 66% among diabetic patients undergoing cardiac surgery. For this reason, it is generally recommended that blood glucose levels should be maintained in the perioperative period between 120 and 180 mg/dL (6.7–10.0 mmol/L) based on expert consensus opinion using cumulative research data. This value range would provide maximum clinical benefit while minimising the risk of developing hypoglycaemia. More stringent strategies aiming in lower target glucose levels have been associated with a higher rate of developing hypoglycaemia; therefore, they are usually not recommended routinely for use [36].

A variety of dietary strategies exist to help maintain normal control of blood glucose, including not taking large amounts of carbohydrate into the body in one meal; spreading carbohydrate intake across the day; aiming to eat only complex carbohydrates of low glycaemic index; eating adequate protein; and timing meals appropriately around the taking of insulin or other glucose-lowering medications [37].

Carbohydrate loading preoperatively is an established practice to reduce insulin resistance and help improve postoperative outcomes for all non-cardiac surgical patients in ERAS protocols. However, there is no evidence to suggest that carbohydrate loading should routinely be undertaken for cardiac surgical patients; therefore, each patient should be assessed individually, in particular those with diabetes or who have impaired glucose tolerance and who may be having their blood glucose levels managed perioperatively [37]. Common operative complications and the injuries that they result in, alongside their respective nutritional management protocols, are shown in Table 1 (Ref. [19,20,22,23,24,25,28,29,30,36,37,38,39,40]).

3.2 Intermediate Phase (Hospital Stay and Early Recovery at Home)

3.2.1 Caloric Adequacy and Gradual Diet Progression

When moving from an ICU to step-down or ward settings, and finally to home, a patient's diet will usually transition from clear liquids to full liquids to soft foods, and finally to a normal, regular diet. This transition should happen as fast as the patient can tolerate and should be based on what symptoms the patient is experiencing and how well they are able to eat, rather than following strict, predetermined timelines [4,5].

There is little evidence supporting the need for prolonged fasting or extended periods of clear liquid diets, yet these two practices commonly result in delayed nutritional recovery and longer hospital stays, without robust evidence supporting their clinical benefit. At this point, nutritional counselling should focus on helping patients get enough calories while progressing toward a heart-healthy diet [7].

Patients will frequently have a decreased appetite during this time, and this may continue for two to four weeks after heart surgery. Some ways to help patients get enough calories include having five to six small meals per day instead of three large meals and choosing energy-dense and

Table 1. Common postoperative complications after cardiac surgery and corresponding nutritional management strategies.

Postoperative problem	Nutritional strategy	Key supporting references
Nausea/vomiting	Small frequent meals; cold foods; multimodal antiemetics; avoid strong odours	[40]
Dysphagia	Texture modification; speech-language pathology consultation; alternating liquids/solids	[28]
Constipation	Fibre 25–30 g/day; adequate fluids; stool softeners; mobilisation	[28], [29]
Fluid overload	Sodium restriction 2–3 g/day; fluid monitoring; diuretics as needed	[30], [39]
Hyperglycaemia	Carbohydrate consistency; low GI foods; insulin protocol	[36], [37]
Poor appetite	Nutrient-dense foods; ONS; small frequent meals; family involvement	[30], [36], [37]
Delayed wound healing	Protein 1.5–2.0 g/kg/day; vitamin C 500–1000 mg; zinc 15–30 mg; vitamin D	[30], [36], [37]

Common postoperative complications after cardiac surgery and corresponding nutritional management strategies. This table outlines frequent postoperative complications encountered after cardiac surgery and provides practical, nutrition-focused interventions aimed at symptom control, prevention of secondary complications, and optimisation of recovery. Nutritional strategies summarised from references [19,20,22,23,24,25,38]. GI, gastrointestinal.

protein-dense foods that will provide the patient with maximum calorie and protein intake per bite [4].

Many patients will also be advised to continue using oral nutritional supplements during this time. In general, a temporary relaxation of "heart-healthy" dietary restrictions may be appropriate, as the priority for these patients will be adequate calories and protein. Stricter dietary modifications can be implemented over time as the patient's nutritional status and appetite improve [4].

3.2.2 Micronutrient Support for Wound Healing

Following median sternotomy, the sternum typically requires approximately 6–12 weeks to achieve sufficient mechanical stability and up to 6 months for complete osseous healing. Meanwhile, it is important that patients are well nutritionally supported so that all the many micronutrients involved in the metabolic processes underpinning bone formation, collagen and tissue healing are there [41].

Vitamin D deficiency (<80 nmol/L) is frequently seen in cardiac surgery patients in a number of studies, and so the general advice is for peri-operative and postoperative patients to take cholecalciferol (vitamin D_3) supplements of around 1000–2000 IU/day, due to its central role in calcium absorption, bone mineralisation, and musculoskeletal health. Patients who are documented deficient will require higher doses of replacement therapy supervised by a clinician [42].

Vitamin C is an important factor in collagen synthesis and wound healing, basically acting by stimulating the hydroxylation of proline and lysine residues. Around 500–1000 mg/day of vitamin C supplementation is taken to help recovery post-operatively. Zinc is, as mentioned before, a significant co-factor of many of the enzymatic reactions associated with protein synthesis, immunity, and tissue repair, so supplementation at optimally about 15–30 mg/day is the usual practice in patients with documented deficiency or impaired healing. In acute postoperative states, this is usually of short duration (2–4 weeks); high-dose long-term supplementation may be unwise as this interferes with the absorption of copper, leading to a secondary deficiency of that element [22,43].

Patients with chronic blood loss or increased iron requirements, and those with perioperative and/or chronic iron-deficiency anaemia, should also receive iron supplementation. The most commonly prescribed form is ferrous sulphate (325 mg/day) or equivalent formulations in order to improve oxygenation of healing tissues. Vitamin K is also important for healthy bones, but its use for supplementation is not appropriate for all patients who are on anticoagulant therapy; therefore, its use for supplementation must be highly individualised [41,44].

3.2.3 Managing Medication-Related Gastrointestinal Disturbances

Gastrointestinal function and nutrient absorption can be temporarily upset in patients who are prescribed multiple medications after cardiac surgery. Opioid analgetics to relieve pain subsequently post-surgery also constipate and nauseate patients and delay gastric emptying, thereby limiting oral intake and contributing to nutritional inadequacy [4,45].

Early transition to non-opioid or multimodal analgesic means, as best seems warranted, would be helpful in management, as would prophylactic dosing of stool softener/stimulant laxative, good hydration within the limits suggested, and food providing 25–30 g of dietary fibre per day (fruit, vegetables, whole grains) to encourage normal bowel function [45].

Patients receiving amiodarone to prevent postoperative AF or to treat it will be subject to gastrointestinal (GI) side effects, including nausea and a metallic taste; rarely, it may permanently damage the liver due to its hepatotoxicity. Patients should be told to take amiodarone with food to minimise GI discomfort and to promptly report prolonged nausea, changes in taste perception, and anything else in the GI tract that upsets their diet [46,47].

Patients in general will receive acid suppression on proton pump inhibitor (PPI) or histamine (H_2) antagonist for stress ulcer prophylaxis for a few days during the perioperative period. Chronic use of acid suppressive medications is known to impair absorption of the micronutrients such as vitamin B12, magnesium, and calcium, but their short use as typical in perioperative therapy is unlikely to produce deficiency states. Caregivers and patients should however be aware of the potential for long-term therapy to cause micronutrient deficiency states [48].

3.2.4 Monitoring for Fluid Overload or Dehydration

The intermediate recovery phase also requires objective volume assessment so that fluid balance can be assessed. Weight gain of more than 5% from baseline, peripheral edema, pulmonary congestion, and worsening dyspnea will all suggest fluid overload.

Conversely, increasing diuretic therapy during the recovery phase may put the patient at risk for dehydration, particularly affecting older patients or patients with good renal function, who may experience pronounced diuresis. Signs of dehydration also include orthostatic hypotension, oliguria (<0.5 mL/kg/h), increasing blood urea nitrogen and creatinine, and concentrated urine [49].

Circulatory status and serum sodium should be monitored frequently, since signs of hyponatremia may result from a free water flush or diuretics; signs of hypernatremia generally are due to insufficient intake or excess fluid losses. While fluid and sodium intakes should not be arbitrarily restricted, targets should be based on objective clinical parameters and lab tests. The overall clinical status of each patient, their cardiovascular and renal function, and their presence or absence of volume overload should be factored into setting individualised targets [50].

3.2.5 Appetite Changes and Psychological Barriers

A significant number of patients experience rather intractable anorexia throughout the postoperative recovery period following cardiac surgery, which in such cases appears to be due to a combination of factors (e.g., low-grade inflammatory effects, drug side effects, undertreatment or improper treatment of pain, discomfort in breathing, depression, and an altered sense of taste). Such features also complicate nutritional laboratory assessment of the patient, thus stressing the importance of the clinical evaluation [51,52].

Delays in the recovery process and poor operative outcomes can result from postoperative depression that affects up to 20–30% of patients undergoing cardiac surgery, and is associated with reduced nutritional intake, delayed recovery, and poorer overall outcomes. Health care professionals should assess patients regularly for depressive symptoms, using validated tools, so that symptoms can be treated as soon as they emerge. Patients may be left with an altered taste, possible metallic taste, or decreased sensitivity to taste for many weeks to months after surgery; this prevents them from enjoying their meals and may further diminish their appetite [51].

The treatment of appetite loss and alterations in taste should focus on the development of patient-centred approaches. Foods and flavours recommended to patients should be tailored to their preferences to support adherence to prescribed nutritional therapy, while ensuring that overall nutritional goals are consistent with established guidelines. Food marination or seasoning using spices or herbs can improve flavour profiles while adhering to individual sodium limits. Meals should also be served at appropriate temperatures to maintain sensory appeal. We encourage patients to eat foods that they enjoy; however, we do not pressure them to do so, as their behaviour may be affected by changes due to the recovery process. Patients' families should be encouraged to plan and help prepare available home foods, providing accessible and familiar foods suited to the patient's particular taste and culture, to improve the patient's nutrition and mental health in recovery [52].

3.3 Long-Term Phase (Weeks to Months After Surgery)

3.3.1 Transition to Heart-Healthy Dietary Patterns

As patients complete the acute recovery phase and enter long-term rehabilitation, nutritional priorities shift from maximising energy and protein intake for tissue healing toward establishing sustainable, cardioprotective dietary patterns aimed at reducing cardiovascular risk factors and slowing disease progression.

The Mediterranean diet is characterised by a high intake of fresh fruits and vegetables (typically around 5–9 servings per day), whole grains, legumes, nuts, and olive oil as the primary source of dietary fat, with moderate consumption of fish and poultry and limited intake of red and processed meats [53,54,55,56]. It also includes moderate consumption of fish and poultry, limited intake of red meat, and optional moderate red wine consumption with meals. Evidence from the Prevention with Mediterranean Diet (PREDIMED) trial demonstrated that adherence to a Mediterranean dietary pattern is associated with significant reductions in major cardiovascular events, including myocardial infarction, stroke, and cardiovascular mortality [53]. These findings support the role of Mediterranean-style dietary patterns in long-term cardiovascular risk reduction among patients with established cardiovascular disease or those at high risk.

The DASH diet has many of the same foods (fruits, vegetables, whole grains, low-fat dairy, lean sources of protein/nuts/legumes) and lowers sodium (no more than 2300 mg/day, ideally 1500 mg), red meat, sweets and sugar-sweetened beverages. There is a considerable body of evidence supporting both dietary approaches, and they can work into many lifestyles. Dietary change should occur gradually rather than abruptly to promote adherence and long-term sustainability [53,54].

Practical strategies for supporting the adoption of heart-healthy dietary patterns are: adding one additional serving of vegetables to the daily diet; using only whole-grain options instead of refined grain options; consuming two or more servings of fish each week; cooking and/or using olive oil in salad dressings; choosing nuts for snacking instead of processed snack foods; and progressively reducing sodium intake by cooking meals from scratch and regularly reading food labels [54].

3.3.2 Weight Management and Preventing Sarcopenia

Patients with a body mass index (BMI) ≥25 kg/m^2 who are overweight or obese may obtain clinically useful improvements to their blood pressure, lipid profiles, and general glycaemic control via gradually shedding between 5 and 10% of total body weight. However, weight loss strategies following cardiac surgery must be implemented cautiously to avoid excessive loss of lean body mass, particularly in elderly patients who are already at increased risk of sarcopenia [57].

Sarcopenia is a gradual decline in skeletal muscle mass and function and occurs in approximately 40–50% of older adult patients undergoing cardiac surgery. Sarcopenic patients almost invariably suffer a greater burden of postoperative complications, length of stay and mortality rates than the comparable patient with no sarcopenia undergoing surgery of that type. Developing and delivering interventions and nutrition screening for older adult patients to address and manage sarcopenia requires sufficient protein intake coupled with some form of resistance training or strength training as part of a structured cardiac rehabilitation program [58].

Older adults can benefit from supplementation with essential amino acids, specifically those with extra leucine [58] or β-hydroxy-β-methylbutyrate (HMB), to help support muscle mass and muscle protein synthesis. Maintaining energy intake (30–35 kcal/kg/day) and protecting protein intake becomes more important than intentional weight loss, even for patients with a high BMI. The combination of obesity and under-nourishment, also called sarcopenic obesity, is a serious concern and requires extremely careful nutrition and functional assessment to develop individualised intervention strategies [59].

3.3.3 Controlling Lipids, Hypertension, and Glycaemia

After cardiac surgery, the long-term diet will need to further encompass multiple risk factors for heart disease, including hyperlipidemia, hypertension, and poor glycemic control at the same time. The composition of fat is a major treatment focus for lipids; the current recommendations are to limit saturated fat to <7% of total energy and emphasise lean sources of protein, lower-fat sources of dairy, and non-tropical vegetable oils. The complete avoidance of trans fat from the diet is crucial [60].

Diet should be adequate in cardioprotective nutrients; omega-3 fatty acids from fish (i.e., salmon, mackerel, sardines) two or more times weekly or by supplementation if food intake is poor, and if at all possible, more soluble fibre (10–25 g/day) from oats, legumes, apples, and citrus fruit [60].

Blood pressure should be managed according to elements of the DASH dietary plan including: more potassium (about 4700 mg/day from fruits, vegetables, and dairy products); magnesium and calcium; less sodium (less than 2300 mg/day, with a goal of less than 1500 mg/day, especially for those with high blood pressure); alcohol moderation (1 drink for women/day, 2 drinks for men/day); and most importantly, weight loss to a healthy body weight [61].

People with diabetes mellitus will also benefit by improvement in blood glucose management if the amount of carbohydrate consumed per meal/protocol is consistent (45–60 g of carbohydrate/meal), the use of glycemic index (lower glycemic index foods), an adequate amount of total dietary fibre (25–30+ g/day), and consistent meal timing relative to the administration of glucose lowering medications or insulin [62].

3.3.4 Special Dietary Adjustments for Comorbidities

Diet is individualised according to the degree of renal function, progress of the disease, and clinical circumstances. Patients with advanced stages of CKD who are not yet on dialysis should aim for a relatively low protein diet (0.6–0.8 g/kg/day) to perhaps slow the rate of deterioration of kidney function, provided they are not energy deficient (target 30–35 kcal/kg/day) and protein–energy wasting is avoided [63].

Total phosphate intake in patients with CKD should be limited to approximately 800–1000 mg/day. Potassium intake should be guided by serum levels and mode of excretion, and fluid intake should be guided by urine volume, volume status, and cardiovascular implications [30,31].

Patients with heart failure are often protein sufficient, and adequate protein intake (1.0–1.2 g/kg/day) should be ensured. Sodium intake should be limited to no more than 2–3 g/day, and fluid restriction should take into account the individual degree of congestion, symptom load, and degree of renal insufficiency [30].

3.3.5 Alcohol, Caffeine, and Smoking Cessation

If alcohol is being partaken of, then consumption should be modest: at or below moderate levels, less than one standard drink per day for women or less than two for men. Problematic use can exacerbate heart failure, induce arrhythmias, worsen blood pressure or provoke adverse interactions with cardiovascular medications. Patients recovering from alcoholic cardiomyopathy or advanced heart failure may, in many cases, need to adjust with complete abstinence from alcohol in order to optimise their clinical outcomes [64].

Table 2. Phase-specific nutritional priorities and practical dietary interventions after cardiac surgery.

Recovery phase	Nutritional priorities	Practical interventions	Key risks addressed	Key supporting references
Early ICU (0–3 days)	Early enteral nutrition; prevent catabolism	EN within 24–48 h; gradual calorie increase; glucose control	Muscle loss, infection, PICS	[25], [66]
Step-down unit (4–7 days)	Protein optimisation; oral intake	High-protein diet; ONS; swallow screening	Poor intake, dysphagia	[25], [66]
Hospital recovery (1–2 weeks)	Caloric adequacy; wound healing	Nutrient-dense meals; micronutrient support	Delayed healing	[41], [42]
Early home recovery (2–6 weeks)	Appetite restoration; weight stability	Small frequent meals; relaxed restrictions	Weight loss, fatigue	[53], [54]
Long-term (>6 weeks)	Cardiovascular prevention	Mediterranean/DASH diet; lifestyle counselling	Disease progression	[53], [54]

Phase-specific nutritional priorities and practical dietary interventions after cardiac surgery. DASH, Dietary Approaches to Stop Hypertension; PICS, persistent inflammation, immunosuppression, and catabolism syndrome.

Patients should also avoid excessive caffeine intake. For patients recovering from cardiac surgery, caffeine intake is recommended to be limited to approximately two cups of coffee (containing 200 mg of caffeine) per day. Individuals with a history of arrhythmias or sleep disorders should be particularly cautious and ensure that their intake remains below this limit.

Smoking cessation is an important part of secondary prevention after cardiac surgery. Smoking increases the risk of graft failure after coronary artery bypass graft (CABG); it also increases the risk for future cardiovascular events and death. All patients who smoke should be provided with a full complement of smoking cessation offerings—behavioural therapy, nicotine replacement therapy, and evidence-based treatments with medications such as varenicline and bupropion. All smoking cessation programmes should ideally begin before surgery and extend indefinitely so that the patient enjoys a long-term benefit for their cardiovascular health [65]. Table 2 (Ref. [25,41,42,53,54,66]) contains an overview of the recommendations for dietary texture and nutritional priorities for patients recovering from cardiac surgery, presented by phase of the postoperative recovery process. Fig. 2 demonstrates the recommended progression of food texture and nutritional priorities after cardiac surgery by phase.

4. Special Populations and Conditions

4.1 Elderly Patients

Nutritionally, patients older than 65 years undergoing cardiac surgery also present unique nutritional challenges. As many as 40–60% of these cases are malnourished preoperatively, upwards of 40–50% will develop sarcopenia, many have swallowing difficulties and are often unable to consume adequate oral nutrition when able to tolerate extensive nutritional support. Another challenge to nutritional management of the older adults lies in the fact that they may have multiple comorbidities, age-induced changes to their physiology and an anabolic blunting that leads to decreased anabolic responsiveness. As mentioned, older adults in general have higher protein needs than their younger cohorts for recovery and maintenance of their skeletal muscle mass [67].

To support and maintain skeletal muscle in older adults, a protein intake of 1.2–1.5 g/kg/day is suggested. In the instance of sarcopenia, protein requirements have been speculated to be higher at 1.5–2.0 g/kg/day to recover from the effects of surgical stress. Sarcopenia screening should be carried out pre-operatively using validated screening tools such as the Strength, Assistance in walking, Rise from a chair, Climb stairs, and Falls (SARC-F) questionnaire, where available [68].

A number of more recent international consensus statements, including the recent definition from the European Working Group on Sarcopenia in Older People (EWGSOP2), regarding the management of older adults and the management of sarcopenia, all suggest that protein intake be graduated by degree of sarcopenia-based functional impairment [69]. Older adults without definite sarcopenia but at risk of developing it should aim for protein intake at the level of 1.0–1.2 g/kg/day, which should be increased to 1.2–1.5 g/kg/day in the acutely or chronically ill [70].

The patient with a mild to moderate degree of sarcopenia (low muscle strength & low muscle mass, but no major functional impairment) should aim for 1.2–1.5 g/kg/day for protein intake apportioned evenly throughout the day to trigger the greatest amount of muscle protein synthesis throughout the day [70,71]. The patient with a severe degree of sarcopenia (low muscle strength, low muscle quantity or quality, and/or decreased physical performance) should aim for protein intake at the level of 1.5–2.0 g/kg/day, where renal function is adequate and/or renal monitoring is done [70,71,72].

Protein quantity and quality (bioavailable protein) consumed at or around each meal, and even the timing of

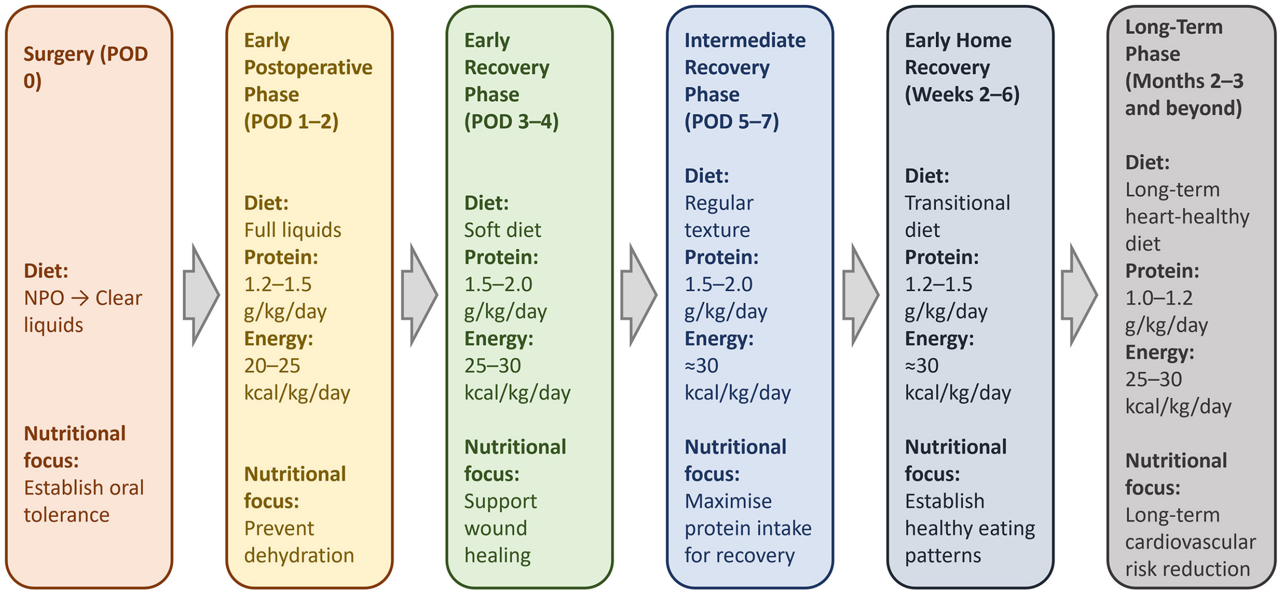

Fig. 2. Dietary Phase Progression after Cardiac Surgery. A progression of diet texture and nutritional focus is illustrated for the various phases of recovery after cardiac surgery, from the immediate postoperative period through long-term rehabilitation. In the early phases, oral or enteral intake tolerance and prevention of dehydration are the highest priorities, followed by progressive increases in energy and protein provision to facilitate wound healing and the maintenance of lean body mass. In the later phases, the dietary strategies transition from those intended to provide sufficient energy and protein to those designed to achieve sustainable heart-healthy eating patterns for secondary prevention of cardiovascular disease. Created by the authors using Microsoft PowerPoint (Microsoft Corp., Redmond, WA, USA). POD, postoperative day; NPO, Nil Per Os.

those meals, are of great relevance regarding muscle anabolism. More recent evidence points towards older people eating highly bioavailable protein in the region of 25–30 g per meal, with the requisite provision of about 2.5–3.0 g of leucine per meal required to maximally stimulate muscle protein synthesis. When sources of dietary protein are marginal, the addition of leucine-enriched essential amino acids and/or β-hydroxy-β-methylbutyrate (HMB) to the diet is worthwhile in recovery from surgery [73].

Patients identified with sarcopenia are likely to benefit from structured prehabilitation programmes incorporating increased protein intake, resistance or strength-based exercise, and, in selected cases, supplementation with leucine-enriched essential amino acids or HMB. The nutritional risk index, derived from serum albumin and body weight parameters, represents a practical screening tool that correlates well with sarcopenia and has demonstrated predictive value for postoperative complications in elderly cardiac surgery patients [74].

Dysphagic conditions (e.g., swallowing disorders) are common in the older population and are often the result of normal age-related changes in the biomechanics associated with swallowing, an increase in the number of individuals who have pre-existing neurological diseases, and an increased risk of developing dysphagia after being extubated. Current guidelines recommend that regular comprehensive swallowing assessments take place; in addition to food texture adaptations, appropriate swallowing therapy should be provided as indicated. Small, frequent meals that are nutrient-dense typically satisfy the appetite and gastrointestinal capacity of the older adult patient better than larger meals. The active participation of family members in planning menus and preparing meals for their cardiac-surgical patients contributes positively to adequate or increased nutritional intake, adherence to an appropriate diet, and outcomes after cardiac surgery for elderly patients [51].

4.2 Patients With Diabetes Mellitus

30–40% of patients who undergo cardiac surgery will have diabetes mellitus, which affects the nutritional management and outcomes on and after surgery. It is prudent to obtain the best possible glycaemic control prior to surgery, and a target glycated haemoglobin (HbA1c) <7% is sensible in many diabetic patients. Perioperatively, blood glucose levels should be kept in the range 120–180 mg/dL using standard insulin protocols; the rates are for good glycaemic control, and hypoglycaemia is the inevitable consequence of the former [75].

For those with diabetes, keeping meals as regular as possible can help minimise glycaemic variability. By eating a similar total amount of carbohydrate for all three meals (around 45–60 g of carbohydrate per meal for women; 60–75 g for men), stable levels can be achieved after the meal and insulin or other treatment to lower blood glucose can be better adjusted. Low glycaemic index (GI) carbohydrate sources should be chosen to reduce the height of the peak post-prandial hyperglycaemia. Eating the recommended amount of dietary fibre (25–30 g of fibre or more per day and about 7–10 g of soluble fibre per day) may improve glycaemic control and lower cardiovascular risk [76].

The timing of food intake must match the timing of the full effect of the remedies used for diabetes, both to avoid the danger of hypoglycaemia. Those on insulin must eat, particularly carbohydrates, when the action of the insulin they are using is starting and maximal, and tapering thereafter. Those taking oral hypoglycaemic medications must eat their regular amount of carbohydrate (at each meal) or risk hypoglycaemia [77]. There are some special considerations of the use of the newer agents which lower blood glucose in the perioperative period. Sodium-glucose cotransporter-2 (SGLT2) inhibitors are usually held for a few days prior to any surgical procedure to avoid the risk of developing an euglycemic diabetic ketoacidosis. Glucagon-like peptide-1 receptor agonists (GLP-1RAs), if utilised, may also have a delaying effect on gastric emptying and should be held in this phase of care to reduce the risk of aspiration in those patients at increased risk of gastric emptying delay related to planned procedures. GLP-1RAs may be restarted when reliable oral intake and gastric tolerance have returned [78,79].

4.3 Patients With Renal Dysfunction or on Diuretics

Roughly 15–20% of patients who have cardiac surgery have CKD. CKD has a major effect on perioperative and long-term nutrition. For those with early-stage CKD (stages 1–3), protein intake is recommended in the range 0.8–1.0 g/kg/day to help with recovery without unduly stressing the kidneys, and for those with late-stage disease (stages 4–5) not on dialysis its recommended intake is 0.6–0.8 g/kg/day to assist in slowing the pace of progression, provided that energy intake is satisfactory [80].

Adequate caloric intake (30 to 35 kcal/kg/day is usually necessary) is needed to prevent protein and energy wasting (PEW) that can occur in CKD patients, leading to adverse outcomes. Very low-protein diets (0.3–0.4 g/kg/day) supplemented with ketoanalogues have been shown to delay the initiation of dialysis in selected patients; however, such regimens require close supervision by experienced multidisciplinary teams to minimise the risk of malnutrition and micronutrient deficiencies [80].

If patients with late-stage CKD can limit their phosphorus intake to approximately 800–1000 mg daily, they may reduce their risks of developing secondary hyperparathyroidism or vascular calcifications. Patients with advanced CKD are often able to achieve this by restricting foods rich in phosphorus, like dairy, many processed foods (that often contain phosphate additives), nuts, legumes and whole grains, and ensuring they are obtaining adequate calcium from phosphate binders or other sources [80,81].

Potassium intake and fluid intake must be individually tailored to match the renal potassium removal and serum potassium level for each patient. Individuals with hyperkalemia must have the recommended potassium intake of 2000–3000 mg per day. On the other hand, patients who are being treated aggressively with diuretics and become hypokalemic will probably require potassium supplementation. The fluid management of patients with CKD will be determined by their cardiac demands and renal function with a focus on volume status, urine output, and other clinical indicators [81].

Patients on hemodialysis are often restricted to fluid intakes of 750–1500 mL/day, depending on the volume of urine produced by the patient. Patients with CKD not requiring dialysis should be encouraged to have an individualised target and not a uniform fluid restriction. Sodium intake should be limited to around 2000 mg per day because it can help control blood pressure and reduce fluid overload in all stages of CKD [82].

4.4 Obese and Overweight Patients

Patients undergoing cardiac surgery have a very high prevalence of obesity (roughly 35–40% of patients will have a BMI ≥30 kg/m^2). Obese patients have differing perioperative nutritional requirements and are at increased risk for sternal wound infections and respiratory complications, and prolonged recovery following surgery [83].

In addition to this, the outcomes for obese patients after cardiac surgery can be complicated. This is further described by what is known as the "obesity paradox", whereby patients who carry a moderate amount of excess weight (BMI between 30–35 kg/m^2) may have better postoperative outcomes than normal weight and severely obese patients, the specific reasons for which are still not entirely understood [84].

In the early postoperative period, nutritional support should be focused on maintenance of lean body mass and healing of the surgical incision, rather than the metabolic stress imposed by fasting. For this reason, adequate protein intake will aid in preserving lean body mass and attaining wound healing, with traditional protein prescriptions for postoperative patients in the range of 1.5 to 2.0 g/kg of ideal body weight. In patients where obesity is most severe (BMI of ≥40 kg/m^2), the literature supports that prescribing a higher level of protein may help to maintain this patient population; this is somewhat controversial, so protein prescriptions must be tailored according to metabolic status, renal and hepatic function, and the presence of postoperative complications [85]. In order to properly prescribe protein for obese patients, it is critical to use a standard formula to compute the ideal body weight (IBW) of the patient. Clinically, the Devine formula is commonly applied to derive IBW (kg). IBW for men is derived by taking 50 kg plus 2.3 kg for every inch over five feet; IBW for women is based on a similar formula, starting from 45.5 kg (IBW (kg) = 45.5

kg + 2.3 kg for each inch over 5 feet). If heights are given in centimetres, first convert them to inches (1 inch = 2.54 cm) before computation.

The use of this formula corresponds to the standards used for clinical nutrition and critical care, and will minimise the overestimation of protein requirements in patients who have a significantly increased actual body weight (ABW) [86]. Among patients who are obese, it is recommended to use adjusted or IBW as opposed to ABW for the determination of caloric needs. Two commonly used methods of estimating caloric requirements are using 20–25 kcal/kg based on ABW and 30 kcal/kg based on IBW, based on metabolic status and clinical condition of the patient [85].

In patients with severe obesity (BMI ≥40 kg/m^2) who have an elective cardiac surgical procedure scheduled, weight reduction preoperatively has been shown to be beneficial in reducing liver volume and improving surgical access. However, rapid weight loss immediately prior to surgery is discouraged due to the increased risk of depleting glycogen stores, reducing lean body mass, and becoming nutritionally compromised [87].

If structured weight loss programmes are appropriate, they should commence 4–6 weeks prior to undergoing surgery, and should target a gradual weight reduction of 5–10% of total body weight. These programmes should include a moderately calorie-restricted diet (1200–1500 calories/day), adequate protein intake (1.2–1.5 g/kg of ideal body weight), as well as resistance exercises to minimise muscle loss and maintain functional capacity [87].

Once patients have completed cardiac rehabilitation, the intent going forward for long-term weight control should be through lifestyle changes that can be maintained. Strategies for sustainable lifestyle changes include cardioprotective dietary patterns (i.e., Mediterranean and DASH diet), portion control, and increasing activity levels (150 minutes/week of moderate intensity exercise). Behavioural interventions will assist with the long-term adherence of an individual seeking to make sustainable lifestyle changes. If, after completing cardiac rehabilitation, a patient with severe obesity and obesity-related comorbidities does not attain appropriate weight loss through lifestyle modifications, they may be referred for evaluation for surgical weight loss options (bariatric surgery) [88].

4.5 Patients Requiring Anticoagulants

Vitamin K antagonists, such as warfarin, are commonly prescribed following mechanical heart valve replacement and for stroke prevention in patients with atrial fibrillation. Their use introduces specific nutritional considerations, primarily related to dietary vitamin K intake and the maintenance of stable anticoagulation [89].

Vitamin K plays an essential role in haemostasis and bone metabolism by acting as a cofactor in the synthesis of clotting factors and calcium-binding proteins. Inadequate vitamin K intake impairs normal coagulation and increases the risk of bleeding, whereas excessive or highly variable intake may reduce the effectiveness of vitamin K antagonists and predispose patients to thrombotic events [89].

Variations in Vitamin K consumption can result in variations in international normalised ratio (INR) levels. A high INR can increase the risk of bleeding, whereas if the INR is low, the risk of thromboembolic phenomena is increased. In the past, patients were advised to completely avoid foods rich in vitamin K; more recent studies have shown that consistent intake of Vitamin K is associated with better control of anticoagulation and warfarin management, allowing some patients to continue to eat certain nutritious foods (green leafy vegetables, broccoli, Brussels sprouts, and some vegetable oils) and achieve stable anticoagulation [90].

General recommendations now include maintaining a consistent diet with vitamin-K-containing foods (regular salad portions with meals vs. huge variability), avoiding abrupt changes in the diet, being aware of the vitamin K content of meal replacements and nutritional supplements, and having more INR checks performed with any dietary change. There is a lower incidence of food-drug interactions for direct oral anticoagulants (DOACs), such as dabigatran, rivaroxaban, apixaban, and edoxaban, as compared to warfarin, because the patient on DOAC therapy needs to eat an overall balanced diet on a consistent basis and not drink large amounts of alcohol because of bleeding risk [91].

4.6 Patients With Gastrointestinal Complications or Enteral Feeding Needs

Gastrointestinal complications following cardiac surgery, although relatively uncommon, are associated with disproportionately high morbidity and mortality. The rate reported for GI complications after cardiac surgery ranges from 0.3% to 5.5% in the literature, with mortality exceeding in some series 25% to 87%. Patients with these complications need prompt identification and aggressive, individualised nutritional treatment [92].

GI complications may include paralytic ileus, upper GI bleeding, occluding or non-occluding mesenteric ischaemia, and acute cholecystitis and pancreatitis on very rare occasions. Older patients, patients having prolonged or multiple surgeries and patients receiving vasoconstrictive agents, threatening splanchnic circulation, may all be at risk of developing these complications [92].

Paralytic ileus patients should remain nil per os, and all gastric contents should be emptied through a nasogastric tube. In instances of prolonged paralytic ileus, patients may be provided with a prokinetic agent. Multimodal antiemetic prophylaxis and early mobilisation will hasten the gastrointestinal recovery and contribute to the prevention of postoperative nausea and vomiting [38].

Table 3. Targeted protein goals and nutrition considerations for special patient populations undergoing cardiac surgery.

Population	Protein (g/kg/day)	Special considerations	Key supporting references
Elderly/Sarcopenia	1.2	Leucine-enriched protein; resistance exercise	[68], [39]
Diabetes	1.2	Carbohydrate consistency 45–60 g/meal; low GI foods	[75], [76]
CKD stage 4–5	0.6–0.8	Phosphorus <1000 mg; potassium individualised; adequate energy	[80], [82]
Heart failure	1.0	Sodium <2 g; fluid 1.5–2.0 L; individualised restrictions	[32], [34]
Obesity (BMI >30)	1.5–2.0 (IBW)	Energy 20–25 kcal/kg actual weight; prioritise protein	[85], [96]
On warfarin	1.2–1.5	Consistent vitamin K intake; no avoidance of green vegetables	[89], [90]

Targeted protein goals and nutrition considerations for special patient populations undergoing cardiac surgery. The table identifies tailored nutrition strategy approaches based on population groups at high risk (age, diabetes, kidney disease, heart failure, obesity, and patients treated with vitamin K antagonists). IBW calculated using the Devine formula (see Section 4.4 for definition). CKD, chronic kidney disease; BMI, body mass index; IBW, ideal body weight.

Patients unable to resume oral intake for prolonged periods due to GI dysfunction are at risk for cumulative energy and protein deficits; they will require nutritional support sooner rather than later. Nutritional support should be started by enteral or parenteral means within 48 hours of the inability to eat. Nasojejunal or jejunostomy tube enteral feeding is better tolerated in patients with poor gastric emptying or patients at high risk for aspiration [38,93].

Patients who cannot receive enteral nutrition due to contraindications or inability to tolerate it (e.g., intestinal ischaemia, severe ileus, or bowel obstruction) will need to receive parenteral nutrition. Nutrition should advance to obtain full requirements within 3 to 5 days (with metabolic monitoring), with a primary concern being the refeeding syndrome that can occur [94].

Patients in cardiogenic shock requiring mechanical circulatory support present a unique challenge due to concerns with mesenteric ischaemia and visceral hypoperfusion. Traditionally, this has led to patients not receiving enteral feeds. Nonetheless, emergent data indicate that a gradual advance of enteral feeds starting at a low infusion rate (10–20 mL/h), while gradually advancing based on patient tolerance and remaining within stable hemodynamic parameters, is feasible and safe, with a reported tolerance level of 58% to 67% in cardiac surgery patients [95]. There are identifiable signs in which the patient is not tolerating their feeding (e.g., increased gastric residual volumes, abdominal distension, elevated serum lactate and worsening of hemodynamic instability), and care is required to mitigate complications whilst preserving the benefits of nutritional support and the integrity of the intestinal barrier [95]. Table 3 (Ref. [32,34,39,68,75,76,80,82,85,89,90,96]) displays protein targets and other dietary objectives for high-risk cardiac surgery patients.

5. Evidence-Based Dietary Recommendations

5.1 Macronutrient Composition

5.1.1 Protein

Patients undergoing cardiac surgery have quite an increased requirement for protein compared to a normal healthy person, and, in addition, a cardiac patient's protein requirements vary with the state of the patient, ranging from 1.2–2.0 g/kg/day depending on the severity of illness of the patient, the degree of metabolic stress and complications. Thus, elderly patients and patients with sarcopenia, who are on prolonged mechanical ventilation or have post-surgical complications, may need to have their protein requirements moved upwards to the high end of the usual 1.5–2.0 g/kg/day so as to maintain their lean body mass as well as support their recovery [97].

General recommendations for optimal muscle protein synthesis suggest an even distribution of protein intake throughout the day (approx. 25–30 g protein per meal), and that it may be advantageous to consume high "biological value" source protein first on the plate to meet your protein goals (lean meats, fish, poultry, eggs, dairy products, legumes, etc.). If eating patterns do not provide sufficient dietary protein to meet your needs, then in periods of protein shortfall, a protein supplement (20–40 g protein in protein powder, whey protein) or oral nutrition supplement may be consumed to assist in achieving adequate protein intake [97].

5.1.2 Carbohydrates

The majority of people who have had heart surgery will receive 45–55% of their energy from carbohydrates. This energy is derived primarily from complex carbohydrate sources, such as whole grains, vegetables, fruits, and legumes. In the early postoperative and critical care settings, however, macronutrient ratios are not strictly fixed; nutritional management should prioritise achieving adequate total energy intake while maintaining appropriate glycaemic control and metabolic tolerance. Intake of refined carbohydrates and added sugars should be limited, as these contribute to glycaemic variability and adverse cardiovascular outcomes [98].

Distributing carbohydrate intake over the course of the day will help support stable blood sugar levels and will be critical to patients with diabetes or impaired glucose tolerance. The daily consumption of adequate dietary fibre (25–30 g/day) will assist in the improvement of cardiovascular health, improve blood sugar control, and improve the function of the bowel during recovery from heart surgery [98].

5.1.3 Healthy Fats

Dietary fat should provide about a quarter to a third of the patient's energy needs (25–35% of total daily energy). The majority of these lipids should come from sources of unsaturated fat, such as olive oil, nuts and seeds, avocados and oily fish. Intake of saturated fats should be limited to less than 7% of total caloric intake, while industrially produced trans fats should be eliminated entirely due to their well-established association with adverse cardiovascular outcomes [98].

Polyunsaturated omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), are also vital for cardiovascular protection and modulation of inflammatory responses. They come mainly from oily fish, including salmon, mackerel, sardines and herring (twice a week minimum). When dietary intake is insufficient, supplementation providing approximately 1–2 g of combined EPA and DHA per day should be considered [98].

5.2 Micronutrient Targets

5.2.1 Vitamins

Vitamin requirements may be raised postoperatively since the body has a higher demand laid upon it to repair wounds and to cope with any other factors, such as infection, that place metabolic stress upon it. Vitamin C is needed for collagen formation and tissue repair; it is therefore usual to require that patients receiving convalescence from major wounds should take a dose of 500–1000 mg of vitamin C daily while actually healing.

Vitamin D is needed to absorb calcium from the food and is also involved in bone mineralisation and the healthy functioning of the muscle and bone system. This prohormone is extremely important in ensuring the patient can heal their sternum following cardiac surgery. Generally, about 1000–2000 IU of cholecalciferol (vitamin D_3) is suitable, but if a person has a documented vitamin D deficiency, then their dose may be much higher, and clinical supervision is required to properly manage their supplementation [99].

B-complex vitamins, including thiamine (vitamin B_1), vitamin B_6, vitamin B_{12}, and folic acid, are relevant to energy metabolism and the formation of red blood cells, regulating homocysteine levels in the body. If someone is on a proton pump inhibitor long-term, they can get reduced absorption of vitamin B_{12}, so they may have to supplement vitamin B_{12}.

Vitamin E and other antioxidant vitamins have been suggested for supplementing to improve recovery from mediators of tissue damage (oxidative stress), but the literature on this is still developing, and it cannot be recommended as a routine high-dose supplementation strategy as yet. Further studies need to be conducted to establish the role of these antioxidant vitamins in this patient population [99].

5.2.2 Minerals

There are a number of other minerals which also have a great bearing on healing properties, as well as assisting in the regulation of a patient's immunity and metabolism. Iron supplementation is indicated in patients with documented iron-deficiency anaemia, which is common in the perioperative period due to blood loss and inflammation. A typical regimen consists of 325 mg of ferrous sulphate daily or an equivalent iron preparation, with the aim of improving oxygen delivery to healing tissues [100].

Zinc is an essential trace mineral, intricately connected to protein synthesis, immune response, and tissue repair. Zinc supplementation with 15–30 mg daily will be required in all patients who have a history of zinc deficiency or an inability to heal at a reasonable rate. Selenium is a component of the body's general antioxidant defence enzyme system (glutathione peroxidase), which may avail some protection from oxidative damage, depending upon selenium levels, requiring dosages from 55 µg to 200 µg of selenium supplementation a day [100].

Magnesium and calcium are charged electrolytes with a crucial role in neuromuscular function, cardiac electrophysiology, and bone metabolism. Dietary intake and supplementation, when indicated, should aim to maintain serum levels within the normal physiological range. However, routine prophylactic supplementation of magnesium or calcium has not been shown to prevent postoperative atrial fibrillation and is therefore not routinely recommended in the absence of documented deficiency [100].

5.3 Fluid and Electrolyte Management

Post-cardiac surgery fluid requirements vary considerably due to cardiac function, renal function, and whether a patient is volume overloaded or not; for example, the average estimated fluid needs for a patient in this situation who does not have heart failure or an impaired renal system is approximately 15–30 mL/kg/day. For patients with heart failure, the average fluid limit is usually 1.5–2.0 L/day; however, the optimal amount for these patients, rather than conservative estimates, should be determined by taking into account many other factors, such as volume overload, congestion status, serum sodium concentration, renal function, and overall clinical condition. More specific estimates could also be made based on their NYHA class and degree of volume overload present [31,32]. Patients who are receiving hemodialysis should also limit the amount of fluid they drink based on their residual urine output and their dialysis prescription [101].

Sodium intake plays a very important role in the body with respect to fluid balance and blood pressure control. As a rule, patients with cardiovascular disease should restrict their sodium intake to about 2000 to 2300 mg/day. Patients with congestive heart failure may also have to restrict their dietary sodium intake to 1500 to 2000 mg/day, provided that they are able to maintain an adequate diet and get their nutritional needs met [102].

Electrolyte management in the postoperative and recovery phase usually includes maintenance of serum potassium levels of about 4.0–5.0 mEq/L and serum magnesium levels between 2.0–2.5 mg/dL. Some recent studies have found no significant decrease in the rate of postoperative AF with aggressive electrolyte replacement in an attempt to achieve high normal ranges; thus, this may increase rather than decrease the risk for the patient. Consequently, the individualisation of electrolyte replacement for each patient should be based on serial laboratory monitoring, clinical assessment and existing co-morbid disease states as opposed to routine prophylactic administration [103].

5.4 Role of Fibre, Probiotics, and Supplements

Dietary fibre is important for healthy metabolic and gastrointestinal health; it helps improve glycaemic control, support lipid regulation, and promote bowel function. However, in the early postoperative period following cardiac surgery, a patient should have their fibre intake increased over time according to individual gastrointestinal tolerance. Initially, many patients may have poor appetite, irregular movement of their bowel, or be able to consume only a small amount of food. Fibre that is soluble (like oats, legumes, fruits, and psyllium) tends to be tolerated better and should be added to the patient's diet before they are given insoluble fibre (many vegetables and some fruits), which should be increased gradually as the patient's bowel function improves. Once patients are eating their normal diet over two to six months, a daily intake of 25–30 g of total dietary fibre, of which about 7–10 g is soluble fibre, is desirable for long-term benefits to health [98].

Research has been done on whether or not probiotics might help with the maintenance of intestinal lining integrity and decrease infections post-surgery. While some studies suggest beneficial effects, optimal probiotic strains, dosing regimens, and timing of administration have not yet been clearly established, and routine use cannot be universally recommended at this time.

Omega-3 fatty acid supplementation is indicated for patients unable to consume enough omega-3 fatty acid-containing food to meet the daily requirements needed for optimal health (i.e., one to two grams of fish oils per day, combined EPA and DHA). Following surgery, modifications to a person's diet may leave them deficient, and supplementation from omega-3 sources has been shown to carry certain benefits to cardiovascular and inflammatory-related outcomes for surgery patients.

For specific immunonutrition formulas (such as arginine, glutamine, and omega-3 fatty acids) given to patients undergoing cardiac surgery, there is controversy over whether or not they actually benefit patients after surgery. Some studies found that these nutrition formulas reduced the number of complications after surgery, while others found no benefit. In order to determine which patients will benefit and what the best formulations and timing for administration would be, it will be necessary to conduct additional high-quality research.

5.5 Timing of Meals and Small, Frequent Feeding Strategy

In general, after cardiac surgery, a feeding pattern consisting of small, frequent meals is generally better tolerated than the traditional three-meal structure. Continuing to eat five or six smaller meals each day will help to compensate for a poor appetite, maintain a total food intake that is adequate in relation to need, minimise gastric distension and make postprandial hypotension less likely during recovery [104].

This approach also ensures a more continuous supply of nutrients to support tissue repair and wound healing, and facilitates the safe administration of medications that require intake with food. Incorporation of a protein-rich snack in the evening may further support overnight muscle protein synthesis and help preserve lean body mass [105].

Patients on insulin therapy for diabetes mellitus should have their meals appropriately timed and distributed in such a manner that their carbohydrate content can be predicted with a fair degree of accuracy from day to day, enabling better glycaemic control and minimising the risk of hypoglycaemia. Diuretics should generally be taken early in the day to minimise the chances of developing nocturia and disturbing sleep; they should be taken, however, in such a way and at such times of the day as to ensure that the patient that day receives sufficient fluid such that he or she is "well hydrated" with respect to the prescribed amounts of fluids consumed [29].

5.6 Cultural and Patient-Centred Dietary Adaptation

Effective and lasting nutritional interventions must be tailored to the individual patient's cultural background, religious dietary rules, taste preferences, financial limitations, and cooking abilities. Any one of these factors influences the probability of a successful intervention in that familiar foods, culturally acceptable and proportionately familiar to the patient, are used in planning an appropriate eating pattern which will meet the recommendations.

The individualised, patient-centred approach to diets such as the Mediterranean and DASH diets allows for the utilisation of their core components (decreasing sodium intake and limiting highly processed foods, encouraging healthy fats, and favouring plant-based foods) across numerous cultures and cooking styles. By individualising dietary recommendations within flexible designs, clinicians can assist with nutritional adequacy and patient independence while honouring cultural differences [106].

6. Role of the Multidisciplinary Team

6.1 Collaboration Between Healthcare Professionals

Effective nutritional management after heart surgery requires working with members of the healthcare team, such as cardiac surgeons, cardiologists, intensivists, anaesthesiologists, dietitians, nurses, physiotherapists, and pharmacists. Each contributes within their own area of expertise to maximising positive outcomes. Surgeons are particularly important in identifying risk factors at the time of surgery and also identifying possible complications after surgery that may impact the patient's nutritional requirements and tolerance to food.

For successful multidisciplinary care to occur, there needs to be defined clinical triggers for nutritional interventions along the perioperative continuum. The development of these triggers may differ by institution, but it is recommended that all patients who are deemed to have a nutritional risk before surgery (e.g., significant weight loss; low body mass index; low prognostic nutritional index; or suspected sarcopenia) be referred to dietitian-led nutritional optimisation (nutrition care) and prehabilitation as part of their care process [8]. After surgery, it is particularly important to have a multidisciplinary review of a patient when they consume less than 60–70% of their required energy or protein within 3–5 days after surgery. Other examples of significant symptoms that can trigger a postoperative nutritional multidisciplinary review include significant gastrointestinal intolerance, a patient on a ventilator longer than anticipated, a patient who shows signs of fluid imbalance and/or who experiences dysphagia or delayed wound healing [24]. During the later parts of each individual's recovery, dietitians, cardiologists, and other rehabilitation specialists/nurses will continue to work together in adjusting diet strategies, monitoring weight and metabolic parameters, and reinforcing long-term cardioprotective diets. Establishing formalised communication processes and criteria for early referrals within the multidisciplinary team will ensure timely nutritional intervention and continuity of care across the surgical recovery continuum [8,24,107].

The dietitian is the specialist responsible for performing comprehensive nutritional assessments, estimating energy and protein requirements, and developing nutrition care plans for each patient. The nurse assists in feeding patients, monitoring oral and enteral intake, and keeping track of the fluid balance of the patient, which enables the nurse to assist the dietitian in determining the progress toward nutritional goals. Pharmacists assist with identifying drug/nutrient interactions, managing gastrointestinal complications associated with medications, and ensuring the compatibility of nutritional therapy and pharmacological treatment [108].

Studies have demonstrated that ICUs that provide dietitian services on a dedicated basis have better nutritional outcomes compared to ICUs that do not provide nutrition support services. Specifically, ICUs with dietetic participation have provided higher prescribed protein targets (1.4 g/kg/day) to the patients compared to patients in ICUs without dietitian involvement (1.1 g/kg/day) and have provided a higher actual protein intake (0.6 g/kg/day) compared to patients in facilities that did not have dietitian support (0.4 g/kg/day). Furthermore, nutrition status is monitored at regular multidisciplinary meetings, which helps to identify patients at risk for delayed recovery and allows timely interventions to improve compliance with nutritional goals and recovery in the postoperative period [4].

6.2 Importance of Patient Education and Family Involvement

Documentation that highlights various possible changes is not sufficient; rather than an absolute measurement of health status, documentation will serve as a guide in sustaining the appropriate change in eating habits. Maintaining a lifestyle of healthy eating and exercise over a long period of time will help improve the patient's quality of life and health. Additionally, the family will be viewed as key to supporting the patient in their efforts to make healthy lifestyle choices. Education will provide guidance for the patient as well as their family members to make informed choices regarding their diet and lifestyle. Family members who participate and are involved in nutritional counselling with the patient will enhance the patient's compliance with their nutrition plan and assist with a long-term change in behaviour [109].

To assist in achieving these goals, education/training for family members participating in nutritional counselling should be provided in a way that is suitable based on the patient and family members' literacy level and language background. Providing educational materials to patients and their families in this manner will facilitate the patient and their family having a common understanding of the dietary needs of the patient. Providing other support, such as cooking demonstrations, group classes, peer support groups, and referral to local community-based programmes, will further reinforce knowledge obtained by patients and their families and will drive compliance with their nutritional plan long-term, resulting in improved overall health outcomes and an increased quality of life [54].

6.3 Dietary Counselling Before Discharge and During Follow-Up

Every cardiac surgery patient must receive structured dietary counselling before leaving the hospital; it should be given by a registered dietitian and customised to the patient's nutritional requirements and medical goals. There needs to be a well-defined dietary goal included in the discharge plan, with written information, meal plans that follow the prescribed eating pattern (for example, the Mediterranean or DASH diet), and contact information in order to provide access to the dietitian if there are any subsequent questions or issues [52].

Patients should be seen by the registered dietitian approximately 2–4 weeks after their procedure, then again at 3 months. The purpose of both appointments will be to identify and correct any new nutritional issues, educate about dietary guidelines, check the patient's adherence to those guidelines, and make necessary changes based on their recovery from surgery and changing health conditions over time. In addition, telehealth follow-up appointments for patients who have difficulty coming to the office for their appointment would be beneficial for the patient in order to continue with their nutritional plan and nutrition-related support [54].

7. Challenges, Barriers, and Gaps in Practice

7.1 Patient Adherence Issues

After cardiac surgery, many patients find it difficult to make long-term changes to their diets; this has been well documented in studies. One estimate has found that only approximately 30% to 40% of those suffering from cardiovascular disease (CVD) will be able to stick to the recommended diet six months post-surgery. There are numerous barriers to complying with the recommended diet, such as family/work commitments, a lack of cooking skills or time for preparation, and the perceived or actual high cost of healthy foods. Furthermore, a lack of access to healthy foods in some communities and the fact that modifying long-term eating habits is inherently difficult contribute to these challenges [51].

7.2 Socioeconomic and Cultural Barriers

Many socioeconomic factors have a great influence on food choice and nutrition after heart surgery. Nutritious foods such as fruits and vegetables, fish and seafood, and nuts often cost more compared with high-calorie, "cheap" foods that are produced poorly, and that those with less money can afford and will buy. Others do not have access to a place to buy healthy food, or cannot afford fresh produce and focus on total calories instead of nutrient density. There may also be cultural and language barriers that inhibit effective nutrition education because educational materials may not have been developed with sensitivity to the patient population or may not be in the patient's language. Solutions to these barriers must include culturally sensitive and tailored education interventions as well as consideration for patients' socioeconomic context when developing dietary recommendations [52].

7.3 Limited High-Quality Evidence

There has been increasing recognition of the importance of nutrition in the outcomes of patients who have had cardiac surgery, but there is still not enough quality evidence on this topic. There have been few randomised controlled trials of nutritional interventions specifically for patients who undergo cardiac surgery. Therefore, the majority of the guidance that we currently have comes from observational studies, small single-centre trials, or studies of other surgical or critically ill populations.

Many areas of research are still lacking sufficient evidence to answer important questions (i.e., optimal energy and protein requirements, timing and composition of immunonutrition, role and dosage of certain micronutrients, and effective nutritional strategies for vulnerable subgroups such as older adults with sarcopenia, patients with advanced heart failure, or patients with concurrent CKD). Well-designed multicentre randomised trials are needed to address these gaps to enhance the evidence base for developing more precise, standardised guidelines for nutrition in patients undergoing cardiac surgery [4].

Another important limitation of the studies reviewed is the variability among the various surgical types that are grouped together in cardiac surgery (i.e., isolated CABG, valve surgery, combined CABG plus valve surgery, or complex aorta surgery). While these surgical types are all considered cardiac surgery, there are vast differences in the amount of time that each procedure takes and its associated duration of CPB, inflammatory response, and postoperative complications. These characteristics can all potentially impact metabolic responses, protein breakdown, fluid management, and the recovery of surgical patients.

For example, combined surgical procedures will result in higher levels of systemic inflammatory activation and higher levels of postoperative morbidity than isolated CABG. Likewise, many patients who undergo valve surgery may present with specific hemodynamic conditions such as chronic heart failure or pulmonary hypertension prior to surgery and can, therefore, potentially face additional challenges with respect to fluid management and nutritional status.

Many of the studies that evaluated nutritional strategies did not use stratification based on surgical type; therefore, it is not possible to make specific recommendations for each surgical type from the current literature. Future studies should assess whether different nutritional strategies are appropriate for patients operated upon by distinct cardiac surgical methodologies and whether different metabolic needs based on surgical type justify varying perioperative nutritional protocols.

7.4 Need for Standardised Guidelines

While there are many guidelines on perioperative nutrition now available, none are procedure-specific to the actual surgical procedures performed on patients undergoing cardiac surgery. None addresses the specific needs of the various procedure types. ESPEN guidelines on clinical nutrition in surgery 2025 and ASPEN guidelines discuss nutrition in surgery and provide guidelines for patients undergoing surgery; they do not go into detail to actually meet the patients' cardiac surgery needs. The ERACS guidelines from 2019 mentioned that structured and standard nutritional guidelines need to be developed for postoperative patients [4,5,7,9].

Future standardised nutrition guidelines for patients undergoing cardiac surgery should ideally consist of several core modules that reflect the perioperative continuum of care. First, there should be categorical preoperative screening protocols to identify malnourished patients, sarcopenic patients, or patients at risk for metabolic complications using validated tools such as the prognostic nutritional index or SARC-F questionnaire. Second, there should be defined nutritional “targets” at each phase of recovery, including energy and protein requirements for patients in the early phase of care in the ICU, during their recovery in the hospital, through to long-term rehabilitation. Third, practical algorithms for beginning and advancing oral, enteral, or parenteral nutrition should have specified criteria for which to escalate therapy when anticipated nutritional targets are not met. Fourth, dedicated sections should address common postoperative complications; examples include GI intolerance, dysphagia, fluid imbalance, hypo/hyperglycaemia, etc. Fifth, appropriate nutrition recommendations should be made for patients at higher risk; examples include elderly patients with sarcopenia, patients with diabetes or CKD, obese patients, patients on anticoagulants, etc. Lastly, effective integration of nutrition into the perioperative care pathway should be emphasised (e.g., referral triggers and how nutritionists should communicate with surgeons/intensivists/nurses/rehab providers) [8,24,107].

Creating an international consensus on the nutritional optimisation of patients undergoing cardiac surgery through the establishment of preoperative screening protocols, optimal protein/energy targets, appropriate enteral feeding protocols, the use of immunonutrition, and appropriate long-term dietary strategies will foster consistency of care nationally and internationally. Creating consistent nutritional guidelines for the cardiac surgery patient population will also assist with quality improvement initiatives, foster interdisciplinary teamwork, and ultimately result in improved patient care and more effective healthcare delivery [110].

8. Discussion

Nutrition is still an underused but fundamental part of providing quality care for patients who have had heart surgery. Surgical trauma, CPB and inflammation around the time of the surgery place tremendous pathophysiological stress on the body. Together, these three factors create a very complex metabolic environment for the body. In this metabolic state, there are multiple changes, including hypermetabolism, increased protein catabolism, insulin resistance, movement of fluids between intracellular and extracellular spaces, and changes in the gastrointestinal system. These metabolic changes will significantly increase a patient’s need for nutrition and, if not addressed, will negatively affect the patient’s recovery through delayed wound healing, muscle atrophy, dysfunction of the immune system, and impaired clinical outcomes. There is a growing body of evidence that supports the integration of a structured and systematic nutritional care plan into modern cardiac surgical pathways as a core component of care and not as an adjunct [8,111,112,113].

Timely implementation of nutrition therapy is one of the cornerstones of postoperative care. Providing enteral nutrition within 24–48 hours after surgery has been shown to maintain the integrity of the intestinal barrier, reduce systemic inflammation, and limit total energy and protein deficits incurred during this time period. Meeting protein requirements (1.2–2.0 g/kg/day) plays an important role in the healing of sternal wounds and maintenance of muscle mass in the skeletal system, as well as limiting the catabolic process associated with surgery. In addition, proper management of fluids and sodium ensures the patient’s hemodynamic status is maintained while preventing fluid overload; there are strong correlations between fluid overload and prolonged mechanical ventilation and increased morbidity [114].

In addition to providing macronutrients, optimising the provision of micronutrients plays a considerable part in recovery. Zinc and iron are both also essential trace elements for the production of collagen and for a healthy immune system, along with supplying oxygen to the tissue that is trying to heal from injury. A deficiency of these two trace elements leads to a greater risk of infection and a delay in healing of wounds after surgery. Hence, these kinds of interventions, along with cardioprotective style eating such as the Mediterranean diet and the DASH diet, provide long-term prevention of cardiovascular disease, systemic inflammation and the slowing of the progression of cardiac disease after heart surgery [115,116].

Effective nutritional management following cardiac surgery requires individualised and stage-specific strategies that account for patient-related factors, including age, comorbidities, physical status, and pharmacological therapies. For instance, patients with diabetes mellitus do best with their carbohydrate intake being evened out throughout the day and dovetailed with medications to manage their blood glucose. On the other hand, when planning nutrition for a patient with CKD, we must be vigilant not to push the protein and electrolytes to worsen their condition, nor to push them to protein-energy malnutrition. So, our patients with CKD will do well with careful monitoring of their calorie loading for the sake of protein. Likewise, patients who are obese or sarcopenic benefit from keeping a close eye on their protein intake and, if desirable, restricting their calories. Therefore, to effectively manage a patient’s nutritional intake, clinicians should use flexible and individualised nutritional goals as opposed to using uniform nutritional prescriptions [39,117].

Some populations require additional careful tailoring to their needs. As an example, older adults suffer from sarcopenia and anabolic resistance disproportionately; they should aim for a somewhat higher goal for protein intake than younger adults, and they need to make muscle loss a regular part of their self-monitoring. Older adults taking vitamin K antagonists (like warfarin) will benefit from eating food sources regularly that contain vitamin K, and they will need to maintain a consistent vitamin K intake instead of avoiding vitamin K-rich foods altogether. In contrast, patients who are prescribed direct oral anticoagulants will need to be educated on bleeding management instead of restricting food intake [96,118]. The evidence presented above further supports the need for coordination of nutritional management with pharmacological management and rehabilitation in order to improve coordination of care and outcomes.

The use of a multidisciplinary team approach is critical in order to effectively apply evidence-based nutritional interventions in the postsurgical patient. The multidisciplinary coordination between the dietitian, surgeon, cardiologist, intensivist, and the rehabilitation specialist has been shown to help with improving the patient's nutritional goals, decreasing postsurgical complications (i.e., infection and length of stay in the hospital), and increasing the long-term quality of life for cardiac surgery patients after they return home. Nutrition is identified as a key factor in achieving surgical success as well as improving cardiovascular health after leaving the hospital when nutrition is embedded along with the ERAS pathway [119].

While there is increasing awareness of the role of nutritional management as part of the wider care of patients undergoing cardiac surgery, there remain large evidence-based practice gaps in the literature requiring addressing to potentially inform best nutritional management of the post-cardiac surgery patient. Future work involving nutrition, particularly for the cardiac surgery patient group, must focus on patient-centred nutritional strategies such as: the derivation of individual protein and calorie targets, nutrition that helps support the immune system in the healing process, the benefits of nutrigenomics, and the evidence for appropriate nutrition during the procedure. Well-designed multicentre randomised clinical trials need to be conducted to underpin the translation of the most recent body of nutrition evidence to evidence-based clinical nutritional recommendations, needing to achieve the dual goal of improving rates of recovery from surgery whilst also maximising the benefits of surgery in the long term [120].

9. Future Perspectives

9.1 Role of Personalised Nutrition and Nutrigenomics

Contemporary genetic variation has been tied to how individuals metabolically respond to what we eat and, subsequently, the increased risk someone has to develop diseases such as heart disease. By pinpointing genetic variations in lipid metabolism, glucose metabolism, inflammatory signalling pathways, and markers of oxidative stress, we can identify patients more or less likely to respond positively to a particular dietary pattern, macronutrient distribution, or targeted supplementation after cardiac surgery. Via a genetic profile, an approach to personalised nutrition in patients post-cardiac surgery may fine-tune the optimisation of protein needs, micronutrient supplementation, and anti-inflammatory dietary patterns for "high-risk" groups, such as older adults, as well as patients in whom other dietary patterns can target glycemic control for sarcopenic, diabetic, or chronic kidney patients [121,122].

The clinical use of personalised nutrition based on genetic information is in its infancy. However, nutrigenomic data may lead to new and innovative ways to accelerate recovery from cardiac surgical procedures, reduce the complication rate, and improve cardiovascular health outcomes long-term by combining nutrigenomic information with clinical, metabolic, and lifestyle data. Future research should focus on the application of nutrigenomic information into clinically relevant, cost-effective, ethically appropriate, and practical tools to be used as a routine part of perioperative care [123,124].

9.2 Integration of Tele-Nutrition and Mobile Health Apps

Using telehealth for nutrition services (TNS) and mobile health applications (mHealth app) as a means to provide longer-lasting support post-cardiac surgery is one way to extend access to nutritional counselling after discharge from a hospital. The use of TN and mHealth has significantly improved access to specialised dietetic professionals, particularly for patients facing geographic, mobility, or time constraints that limit in-person attendance. Clinicians using TN or mHealth will be able to provide ongoing care, have more frequent follow-up appointments, and modify current nutrition recommendations based on the evolving clinical situation of the patient [54].

The use of mobile health apps designed for dietary self-monitoring encourages patients to engage in their nutrition care through real-time tracking of their food and fluid intake, as well as their weight. Various mobile health platforms can offer automated responses to entered food items, provide meals based on automated meal planning systems, and suggest culturally relevant recipes. Additionally, there are mobile health apps that provide integration of peer support features and remote communication with a registered dietitian, which helps to motivate patients and provide accountability to their weight-related goals following cardiac surgery. New evidence suggests that digitally mediated nutrition interventions offered through a hybrid of in-person nutrition counselling and TN or mHealth may be a more successful way to improve dietary adherence and provide cardiometabolic benefits to patients post-cardiac surgery than traditional in-person nutrition counselling [125,126].

In order to successfully implement TN and mHealth in the post-cardiac setting, considerations must be made for the existing level of patient digital literacy, data security, and integration into the current healthcare system. Future studies should focus on determining clinical outcomes, developing best practices for hybrid models of care, and determining which patient populations would benefit most from using digital nutrition tools in the post-cardiac surgery setting [127].

9.3 Emerging Evidence on Anti-Inflammatory and Plant-Forward Diets

Increased attention to anti-inflammatory and plant-predominant diets has led to renewed interest in whole-food diets that are high in fruit and vegetables, wholegrains, legumes, nuts and seeds and with little refined carbohydrate and saturated fat from animal sources. It is important to note that the dietary patterns outlined above are rich in dietary fibre, polyphenols, and phytonutrients, which have been demonstrated to modulate inflammation, enhance endothelial function, and decrease oxidative stress, all mechanisms that play an important role after surgery [128].

The well-studied model of the Mediterranean and DASH diets, which incorporate the above anti-inflammatory properties, has been shown to have protective effects on cardiovascular events, metabolic status, and chronic low-grade inflammation. There is interest in research of more exclusively plant-based dietary patterns, with evidence of some cardiometabolic benefits having been shown through effects such as lowering of low-density lipoprotein (LDL) cholesterol, blood pressure, insulin resistance, and inflammatory biomarkers. While there is some initial literature showing evidence of the benefit of use of a plant-based diet for cardiovascular disease prevention and management, more studies are needed on safety, feasibility and nutritional adequacy of a plant-based diet in the postoperative cardiac surgery population, particularly with respect to protein quality, micronutrient adequacy, and long-term adherence [129,130,131].

10. Limitations

There are multiple limitations with this review which need to be identified. While this review identified many possibilities, the majority of the information found via comprehensive literature searches does not provide definitive guidance for those undergoing cardiac surgery due to obvious limitations regarding the design of referenced studies.

Firstly, the multifaceted range in the trials indicated that there was extensive heterogeneity between identified study populations, surgical procedures, nutritional assessment methods used, outcome measures, and intervention methods. The identified heterogeneity will not allow comparison of trials using a quantitative analysis methodology due to the differences found across the various studies; thus, results should be viewed with caution. There is no definitive outcome regarding the optimal macronutrient targets, timing of intervention, or the effectiveness of a particular dietary strategy, depending on the health status of the patient, resulting from the reviewed data.

Secondly, the amount of time required to develop more comprehensive evidence regarding the efficacy and appropriateness of perioperative interventions, enhanced recovery pathways, and electronic health systems impacts the shelf life of any recommendations derived from this review. The studies collected, assessed on an individual patient or health facility basis, may include some emerging research which addresses such things as personalised nutrition, immunonutrition, and digital applications used for dietary management; however, most of these options will require further validation.

Thirdly, the authors of this review have attempted to include considerations for all patient cohorts and all potential comorbidities, yet the heterogeneity found between different healthcare systems, cultural dietary practices, socioeconomic status of diverse populations, and resource availability will all impact the acceptance of the identified recommendations as they relate to the different individual geographic regions throughout the globe. Therefore, it is necessary for researchers to design pragmatic multicentre studies and implementation studies, which will provide more robust evidence to develop a set of standard yet flexible evidence-based nutritional recommendations for patients undergoing cardiac surgery.

11. Conclusion

Effective management of nutrition has a significant impact on patient outcomes, especially for patients who undergo cardiac surgery; however, it is frequently overlooked as a determinant of success. The response of the body to the metabolic and inflammatory stress of surgery is so complex that nutritional status must be established early enough to permit the initiation of nutrition as soon as possible after surgery, providing at least sufficient protein and energy, appropriate micronutrients, and resulting in the maintenance of fluid and electrolyte, all essential requirements throughout the whole course of recovery. Nutrition incorporated into the overall care of patients undergoing cardiac surgery using multidisciplinary pathways, and evidence-based nutritional options will result in lower complications, facilitate recovery and optimum cardiovascular health over the long term. Future trials and procedure-specific nutritional guidelines based on sound evidence will improve the incorporation of nutrition into the care of patients.

Key Points

• Cardiac surgery induces a significant hypermetabolic and inflammatory response that increases energy and protein requirements and places patients at risk of malnutrition, muscle loss, and postoperative complications if nutritional support is inadequate.

• Early initiation of enteral nutrition, adequate protein provision, careful fluid management, and optimisation of micronutrient status are essential components of perioperative care to support wound healing, immune function, and recovery after cardiac surgery.

• Nutritional strategies should be adapted to the different phases of recovery—from intensive care to long-term rehabilitation—with gradual transition toward cardio-protective dietary patterns such as the Mediterranean and DASH diets.

• Special patient populations, including elderly individuals with sarcopenia, patients with diabetes mellitus or chronic kidney disease, obese patients, and those receiving anticoagulant therapy, require individualised nutritional assessment and tailored dietary management.

• Integration of structured nutritional assessment and intervention within multidisciplinary perioperative care pathways, including ERACS protocols, may improve recovery trajectories and reduce postoperative morbidity.

Availability of Data and Materials

The data supporting the findings of this study are derived from publicly available sources. All references used in this review are cited within the manuscript. No new datasets were generated or analysed during the current study.

Author Contributions

Conceptualisation: VL and MD. Literature review and data curation: VL, FM and VA. Methodology and scientific supervision: VL, MD, EK, and NGB. Writing—original draft preparation: VL. Writing—review and editing: FM, SM, AP, PT, and MD. Methodology and scientific supervision: SM, PT. Literature review and data curation: AP, PT. All authors contributed to the important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

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Conflicts of Interest

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