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CLINICAL APPLICATION OF EARLY POSTOPERATIVE NUTRITIONAL SUPPORT IN PATIENTS WITH HIGH-RISK VALVULAR HEART DISEASE

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ABSTRACT—**Background**: The treatment strategy of early nutritional support after cardiac surgery has gradually been adopted. However, there are no scientific guidelines for the timing and specific programs of early nutritional support. **Methods:** A retrospective, single-center analysis (2021–2023) was carried out including elderly patients who were admitted for valvular heart disease and received open-heart valve replacement surgery. We designated patients who started the optimized nutritional support after surgery as the optimized enteral nutritional support strategy TN (EN) group and those who received traditional nutritional support as the traditional nutritional support strategy (TN) group. The nutritional and immune indexes, postoperative complications, length of hospital stay, and hospitalization cost of the two groups were compared and analyzed. **Results:** We identified 378 eligible patients, comprising 193 (51%) patients in the EN group and 185 (49%) patients in the TN group. There was no significant difference in hospital mortality between the two groups, but the proportion of nosocomial pneumonia was significantly lower in the EN group than in the TN group ($P < 0.001$). In the Poisson regression analysis, EN was not associated with an increase in gastrointestinal complications ($P = 0.549$). The EN group also seemed to have shorter hospital stays and lower hospitalization expenses ($P < 0.001$). In the comparison of postoperative gastrointestinal complications, fewer patients experienced diarrhea ($P = 0.021$) and abdominal distension ($P = 0.033$) in the EN group compared with the TN group. **Conclusion:** The optimal nutritional support strategy could effectively improve the clinical outcome of high-risk patients with valvular heart disease.

KEYWORDS—Nutritional support; early enteral nutrition; valvular heart disease; high-risk elderly patients; gastrointestinal complications; retrospective study

INTRODUCTION

Valvular heart disease (VHD) is an increasingly common cardiovascular disease (1–3). With the prolongation of the average life expectancy and the improvement of the health level of the population, along with congenital heart disease, VHD also represents a trend of aging (4–6). The vast majority of cases of this disease are not susceptible to conservative treatment and require valve replacement surgery. Many patients who need valve replacement have critically serious cases (7,8). Especially for people older than 70 years, according to the 2014 American Heart Association/American College of Cardiology guidelines, the diagnosis of severe heart valve disease is usually given at the first medical consultation (9). Therefore, perioperative treatment of such elderly and high-risk patients is very important, especially in postoperative rehabilitation. For this study, we screened patients by EuroSCORE II score and defined patients with EuroSCORE II score >5 as patients with high-risk valvular disease.

The rehabilitation of patients after cardiac surgery is composed of many factors, such as the recovery and improvement of cardiac function, the recovery of vital organs and digestive tract functions in the body, and the improvement of general conditions (10,11). The recovery of gastrointestinal function and the degree of systemic nutritional support have received more and more attention with the growing understanding of the importance of nutritional support in the surgical field (12–14). Postoperative gastrointestinal dysfunction is also a difficult problem to face in perioperative management (15). In one retrospective study, the serious gastrointestinal complications included mesenteric ischemia, hepatopancreatobiliary dysfunction, and gastrointestinal bleeding, with mortality rates of 45%, 27%, and 17%, respectively (15). Therefore, early recognition and aggressive treatment are necessary to improve outcomes.

In cardiac surgery, cardiopulmonary bypass (CPB) is a low perfusion process of nonphysiological tissue. Because of CPB, patients usually experience a period of gastrointestinal hemodynamic disturbance after traditional cardiac surgery, such as gastrointestinal hypoperfusion (16–18). Changes in a large number of factors and media of gastrointestinal mucosa may lead to increased permeability, translocation of flora, and ulcer damage to the gastric mucosal barrier (19). Studies have shown that malnutrition in patients after cardiac surgery is mostly iatrogenic, and most patients after cardiac surgery receive late nutritional support, which leads to longer hospital stays, increased costs, and poorer patient prognosis, among other things (20–22). Postoperative nutritional support is an important part of the prognosis of high-risk patients. Patients with high-risk VHD are at high risk of surgical operation due to cardiac insufficiency, malnutrition, liver and kidney dysfunction, and other factors (23). Improving the postoperative nutritional status of these patients has a positive effect on their prognosis and recovery.

In this study, elderly patients with high-risk VHD were selected as the research object. Combined with the current clinical experience of nutritional support, the traditional nutritional support strategy was optimized to explore the application value of early standardized nutritional support in critically ill patients after CPB.

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METHODS

Study population

We identified patients who were admitted for VHD and discharged from June 2021 to June 2023. These patients all received open-heart valve replacement.

From June 2021 to June 2023, 378 elderly patients with high-risk VHD, 185 males and 193 females, with an average age of 73.97 years, were selected from the patients of the cardiac vascular center of the First Affiliated Hospital of Naval Medical University. Among them, 162 cases underwent mitral valve operations, 135 cases underwent aortic valve operations, and 81 cases underwent double valve operations.

The inclusion criteria were as follows: diagnosed with VHD based on symptoms, echocardiogram, and imaging; ≥70 year of age; cardiac function grades III and IV (New York Heart Association); left ventricular end-diastolic diameter >65 mm; and EuroSCORE II score >5.

The exclusion criteria were as follows: interventional operation, ischemic cardiomyopathy, dyshepatia, renal dysfunction, nutritional disease (such as malnutrition, obesity, vitamin deficiency, hypervitaminosis), intestinal and parenteral nutrition contraindications, energy metabolism disorders, and malignant tumor.

Study design and setting

This was a retrospective cohort study conducted using data from the cardiac vascular center of the First Affiliated Hospital of Naval Medical University.

The study design was an observational study using routinely collected data. The research program was in line with the 1975 "Helsinki Declaration" ethical guidelines. The execution of the study was approved by the Data Processing Committee (First Affiliated Hospital of Naval Medical University) under a waiver of consent. According to institutional policies, retrospective studies utilizing existing, de-identified medical records do not require formal ethical approval. Also, each patient had been informed prior to admission that their clinical data might be used for scientific research, and both the patients and their families signed informed consent forms.

Group assignment

Patients who received optimized nutritional support after operation were defined as the optimized enteral nutritional support strategy TN (EN) group and those who received traditional nutritional support were defined as the TN group. The decision for a patient to receive early postoperative nutritional support or traditional nutritional support was based on the attending physician's clinical judgment. Several factors were considered in making the recommendation: (1) Hemodynamic stability — Early enteral nutrition was initiated for patients who were hemodynamically stable within 12 hours postsurgery. Patients with unstable vital signs were more likely to receive traditional nutritional support. (2) Preoperative nutritional status — Patients with better preoperative nutritional status were considered good candidates for early enteral nutrition. Those with significant malnutrition or other nutritional deficits were more carefully monitored and often started on traditional nutritional support. (3) Presence of comorbidities — The presence of comorbid conditions, particularly those affecting gastrointestinal function (e.g., diabetes), influenced the decision. Patients with fewer comorbidities were more likely to receive early enteral nutrition. (4) Surgical factors — The complexity and duration of the surgery also played a role. Patients undergoing fewer complex procedures were typically started on early enteral nutrition sooner than those with more complicated surgeries.

Two nutritional treatment methods

All enteral nutrition was administered through a nasal jejunal feeding tube with a precision warmed infusion pump at 20 to 40 mL/h.

EN group

Enteral nutrition support started 12 hours after operation on the premise of stable circulation. The specific nutritional support strategies are the following: (1) within the first 24 hours after the first 12 hours after surgery — enteral nutritional suspension (total protein fiber-fructooligosaccharides) (4,186.8 kJ/1 L) 500 mL + slight liquid diet (multinutrient fortified composite powder, 1,578.4 kJ/100 g) 53 g + Ruifuping pectin (20.9 kJ/90 g) 90 g, and total energy was about 2,930 kJ/24 hours; (2) within the second 24 hours — Peptisorb (short peptide type enteral nutrition, 2,122.7 kJ/125 g) 125 g + slight liquid diet 53 g + Ruifuping pectin 90 g, and total energy was about 2,930 kJ/24 hours; (3) within the third 24 hours — Peptisorb 250 g + Ruifuping pectin 90 g, and total energy was about 4,186.8 kJ/24 hours. (4) At 84 hours after operation, nutritional support was determined according to whether the patient stopped using the ventilator. If the patient was out of the ventilator, he/she could eat independently, supplemented by a homogenate diet, and total energy was about 4,187 to 6,280 kJ/24 hours; enteral nutrition (Peptisorb 250 g + Ruifuping pectin 90 g) was still used if the patient was not out of the ventilator, and total energy was about 4,187 to 6,280 kJ/24 hours. (5) All patients with ventilator weaning after operation were given self-feeding supplemented with a homogenate diet, and total energy was about 4,187 to 6,280 kJ/24 hours. (6) Discontinuation of enteral nutrition occurred in the following cases: definite massive gastrointestinal bleeding, intestinal obstruction, or suction of gastric contents over 500 mL within 6 hours.

TN group

No enteral or parenteral nutritional support was given within 72 hours after operation, and only 200 mL 5% glucose infusion was used to protect the gastric mucosa. Enteral nutrition (Peptisorb 250 g + Ruifuping Pectin 90 g) was added for patients who remained on the ventilator 72 hours after operation, and total energy was about 4,186 kJ/24 hours. All patients with ventilator weaning after the operation were given self-feeding supplemented with a homogenate diet, and total energy was about 4,187 to 6,280 kJ/24 hours. Discontinuation of enteral nutrition occurred in the following cases: definite massive gastrointestinal bleeding, intestinal obstruction, or suction of gastric contents over 500 mL within 6 hours.

Variables and outcomes

Covariates included age, gender, height, weight, body surface area at admission; body mass index (BMI) (in kg/m^2) at admission; hypertensive previous history; diabetes previous history; EuroSCORE II at admission; left ventricular ejection fractions, the level of prealbumin, albumin, total protein, globulin, and hemoglobin in blood at admission; the level of serum immunoglobulin A (IgA), serum immunoglobulin G (IgG), and serum immunoglobulin M (IgM) in serum at admission; cardiopulmonary bypass time (CPBT); and aortic occlusion time (ACCT) during operation.

The primary outcome of this retrospective study was to explore the relationship between nutritional support and outcome status, including in-hospital mortality, nosocomial pneumonia, hospitalization duration, and total hospitalization costs. Because the coats were recorded in Chinese yuan (CNY), we converted the amounts into US dollars (USD; CNY 6.70 = USD 1). The secondary outcome of our study was to describe the relationship between nutrition support and nutritional and immune levels, including digestive complications (diarrhea, abdominal distension, vomit, and gastrointestinal bleeding). In the Poisson model of in-hospital mortality, we included nosocomial pneumonia, the duration of intensive care unit (ICU), optimized nutritional support (the EN group or the TN group), and malnutrition (BMI, <18.5 kg/m^2) as covariates. In the Poisson model of gastrointestinal complications, we included CPBT, ACCT, the time of ventilator support, the duration of ICU, and optimized nutritional support as covariates. Patients using the EN strategy had a lower incidence of bloating and diarrhea.

Statistical analysis

Continuous variables were expressed as mean and standard deviation if normally distributed, or as median and interquartile range if the variable was not normally distributed. Categorical variables were expressed as frequencies and percentages. Comparison of continuous variables was by Student *t* test and median test for not normally distributed variables. Chi-square and Fisher exact test were performed to compare categorical variables. Significance was set at a P value of <0.05. Poisson regression methods were used to analyze the correlation of factors with hospital mortality and gastrointestinal complications. In Poisson regression analysis, "RR" stands for "relative risk," sometimes referred to as the "risk ratio." Relative risk is used to describe the extent to which a particular variable (or factor) affects the probability of an event occurring. The IBM SPSS Statistics 25.0 software (IBM SPSS Inc., Chicago, IL) was used for the statistical analysis.

RESULTS

Figure 1 shows a flowchart for the study cohort. After applying all inclusion and exclusion criteria to the VHD population, 378 subjects met the study criteria. Of all the patients admitted for VHD, 167 received conservative drug treatment, 496 subjects received interventional therapy, and 343 subjects did not meet the age and nutritional status criteria, leading to a total of 378 complete cases.

Baseline clinical characteristics

The demographic and clinical characteristics for the complete cases (n = 378), as well as the cases which received early enteral nutrition (n = 193, 51.1%) versus traditional nutrition (n = 185, 48.9%), are shown in Table 1. There was no statistical difference in demographic and clinical characteristics between the two groups.

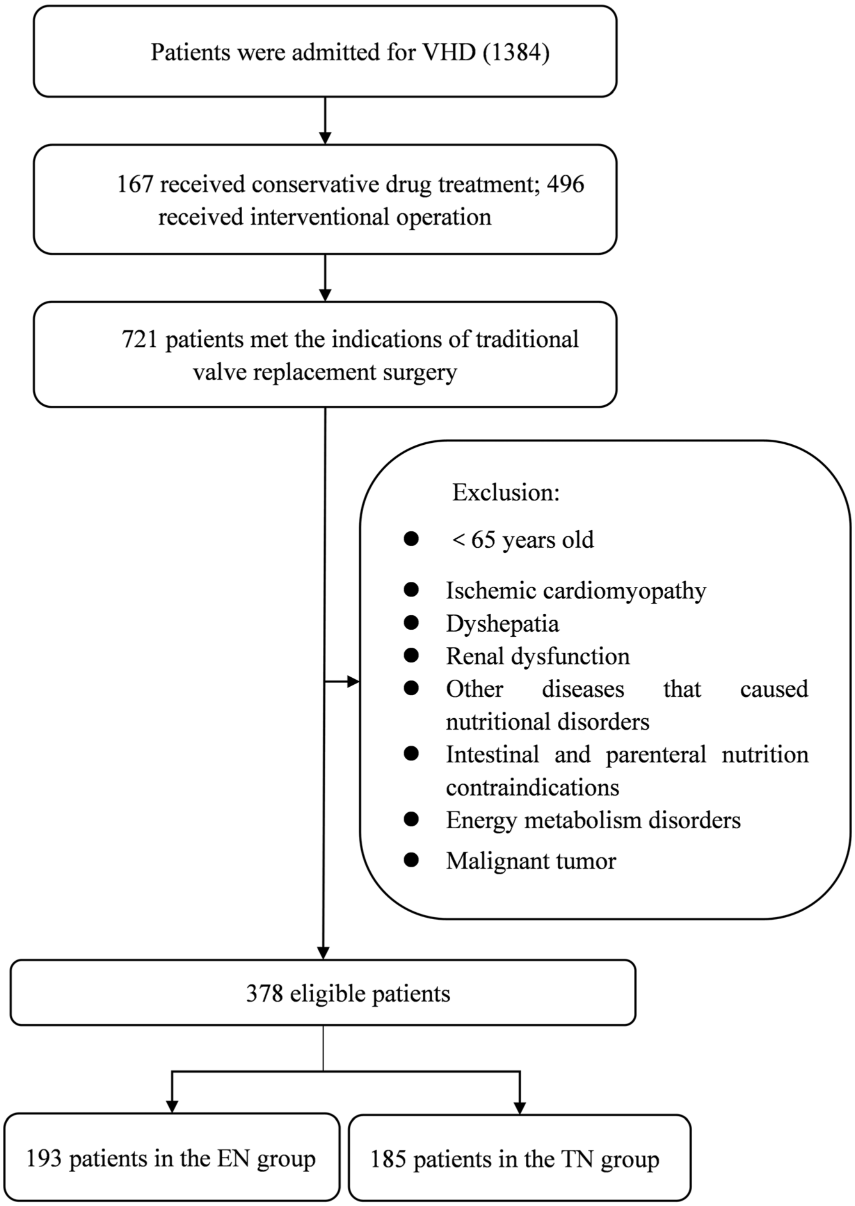

Fig. 1. **Patient flowchart.** EN, optimized enteral nutritional support strategy; TN, traditional nutritional support strategy.

Outcomes

In the Poisson regression analysis, the duration of ICU and pneumonia were the only factors associated with mortality in hospital. More details are summarized in Table 2.

A comparison of outcome variables between the two groups is presented in Table 3. There was no significant difference in in-hospital mortality ($P = 0.081$). However, the proportion of hospital pneumonia was significantly lower in the EN group than in the TN group ($P = 0.029$). The length of hospital stays was significantly shorter in the EN group than in the TN group ($P < 0.001$). Furthermore, the total hospitalization costs were significantly lower in the EN group than in the TN group ($P < 0.001$).

Comparison of nutritional and immune levels on postoperative day 7

Table 4 shows the nutritional and immune statuses of the two groups on postoperative day 7. There was no statistical difference in the overall mean of IgG in the two groups ($P = 0.110$), whereas other indicators representing nutritional status, including prealbumin, albumin, total protein, globulin, hemoglobin, IgA, and IgM, were significantly higher in the EN group.

Gastrointestinal complications in patients on postoperative day 7

Table 5 presents the postoperative digestive complications. The most prevalent complication was abdominal distension in 33 patients (8.7%), followed by vomit in 29 patients (7.7%), diarrhea in 27 patients (7.1%), and alimentary tract hemorrhage in 14 of them (3.7). Eleven of the gastrointestinal bleeding patients had fecal occult blood (+), and the rest of them had fecal occult blood (++~).

There was an association between the use of early enteral nutrition support and the development of abdominal distension (11 patients with EN [5.7%] vs. 22 with TN [11.9%]; $P = 0.033$) and the development of diarrhea (8 patients with EN [4.1%] vs. 19 with TN [10.3%]; $P = 0.021$). There were no statistically

Table 1. **Differences in characteristics of the two groups of patients**

Variable	EN group (N = 193)	TN group (N = 185)	P
Age (year)	73 (70, 77)	74 (72, 77)	0.083
Gender (male/female)	96/97	89/96	0.752
Height (cm)	168 (160, 174.5)	168 (161.0, 174.0)	0.554
Weight (kg)	66 (57, 74)	75 (66, 81)	0.985
BSA	1.74 (1.58, 1.9)	1.68 (1.43, 1.9)	0.812
BMI (kg/m^2)	23.8 (20.9, 26.8)	23.3 (20.3, 26.2)	0.418
Hypertensive	50 (25.9%)	39 (21.1%)	0.270
Diabetes	23 (11.9%)	20 (10.8%)	0.742
EuroSCORE II	7 (6, 9)	7 (6, 9)	0.727
LVEF (%)	53 (46, 60)	50 (42, 56.5)	0.001
Prealbumin (mg/L)	186 (166, 209)	191 (168, 209)	0.738
Albumin (g/L)	39 (36, 43)	40 (37, 42.5)	0.472
Total protein (g/L)	70 (65, 76)	69 (65, 75)	0.377
Globulin (g/L)	25 (22, 28)	25 (22, 28)	0.939
Hemoglobin (g/L)	128 (119, 138.5)	131 (120, 139)	0.203
BNP (pg/mL)	746 (397, 1,095)	862 (434.5, 1,148.5)	0.121
IgA (g/L)	3.51 (2.7, 4.1)	3.1 (2.4, 3.8)	0.004
IgG (g/L)	17.6 (14.7, 20.1)	18.2 (15.7, 21.1)	0.035
IgM (g/L)	1.54 (1.27, 1.76)	1.56 (1.23, 1.77)	0.682

Significant difference, $P < 0.05$.
BSA, body surface area; BMI, body mass index; LVEF, left ventricular ejection fractions; BNP, brain natriuretic peptide; EN, optimized enteral nutritional support strategy; TN, traditional nutritional support strategy.

significant associations between the use of early enteral nutrition support and the occurrence of other digestive complications.

The covariate Poisson regression of gastrointestinal complications

In the multivariable study (Table 6), the factors affecting gastrointestinal complications were the ICU duration (95% confidence interval [CI], 1.003–1.007; $P < 0.001$) and ventilator duration (95% CI, 1.001–1.005; $P = 0.006$).

DISCUSSION

There are little available data on nutritional status, the development of digestive complications, and pneumonia associated with early enteral nutrition support in patients with high-risk VHD after surgical treatment. To our knowledge, this was the first study to analyze these factors in a large elderly population with VHD and show the superiority of early enteral nutrition support over the traditional nutritional support for maintaining higher nutritional and immune levels and for reducing pneumonia and digestive complications, after valvular replacement operation.

The primary outcome of this retrospective study was to explore the relationship between nutritional support and outcome status including in-hospital mortality. Our study included nutrition modality, hospital-acquired pneumonia, ICU duration, and ventilator duration as covariates for the primary outcome variable, in-hospital mortality. Table 2 shows the multivariate Poisson regression analysis of the primary outcome variable of in-hospital death. Multivariate analysis showed that hospital-acquired pneumonia was associated with in-hospital mortality. In addition, longer ICU stays and ventilator use were associated with higher in-hospital mortality. However, nutritional support and preoperative BMI were not associated with in-hospital mortality. This result is similar to the results of studies related to postoperative nutritional support (24–26).

Table 2. **In-hospital mortality Poisson regression analysis**

Variable	RR	95% CI	P
ICU duration (h)	1.016	1.007–1.024	0.001
Pneumonia	148.99	14.323–1,549.797	0.001
EN	1.751	0.281–10.927	0.549
BMI	0.321	0.038–2.735	0.299

Significant difference, $P < 0.05$.
RR, relative risk.

Table 3 describes the differences in outcome variables between the two groups of patients. The results showed that the EN was not associated with in-hospital mortality but was associated with a lower incidence of pneumonia, a shorter length of hospital stays, and lower hospitalization costs. Among them, the length of hospital stays and the total costs of hospitalization were significantly different between the two groups of patients. The length of hospital stays of patients in the EN group was significantly shorter than that for the TN group. The Bristol Biomedical Research Center has used the Cochrane Library to review all registered randomized controlled trials on perioperative nutritional management in gastrointestinal surgery and concluded that early enteral feeding may reduce the length of hospital stay (27). A multicenter randomized clinical trial concluded that early parenteral nutrition increased serum prealbumin and albumin levels, which is beneficial to patients' postoperative recovery (28). In addition, the length of the ICU stay was shortened, and complications of the gastrointestinal tract were reduced (29–32). The authors suggested that early parenteral nutrition combined with enteral nutrition can significantly improve postoperative energy delivery and prevent energy deficits in the first postoperative days (31,33,34). In our retrospective analysis, the hospitalization expenses of patients in the EN group were also significantly lower than those in the TN group. We hypothesized that early nutritional support improves the postoperative nutritional reserve of patients, reduces the incidence of related postoperative complications, shortens the length of stay in the ICU and the total length of hospitalization, and reduces the use of other expensive medications and advanced life support, etc., thus fundamentally reducing the total hospital costs.

The secondary outcome of our study was to describe the relationship between nutrition support and nutritional and immune levels, including digestive complications. In cardiac surgery, low-risk patients can return to normal gastrointestinal physiology in a relatively short period due to their compensation and rapid recovery capabilities, and gastrointestinal and low nutrition-related complications are rarely seen (34–36). However, in elderly and high-risk patients, gastrointestinal ischemia and the release of inflammatory substances caused by CPB are more serious, and related complications are more likely to occur (37–39).

In general, intestinal blood supply accounts for 25% of the total blood supply. When the cardiac output decreases and the sympathetic nerve excites after cardiac surgery, the intestinal blood supply will decrease (40,41). In this case, not only will the intestinal mucosal permeability be increased but also the destruction of the intestinal mucosa by inflammatory mediators and other substances will lead to intestinal edema, which further weakens the ability of the intestine to absorb nutrients, increases protein loss,

Table 3. **Outcomes**

Variable	EN group (N = 193)	TN group (N = 185)	*P*
In-hospital mortality	6 (3.1)	13 (7.0)	0.081
Pneumonia	10 (5.2)	21 (11.4)	0.029
Length of hospital stay (day)	15.0 (13.0, 17.0)	17.0 (15.0, 19.0)	0.001
Total hospitalization costs (dollar)	14,790.8 (12,850.7, 17,211.3)	15,898.4 (13,959.8, 18,542.0)	0.001

Significant difference, $P < 0.05$.
EN, optimized enteral nutritional support strategy; TN, traditional nutritional support strategy.

and affects the metabolic synthesis of the body, which will eventually lead to malnutrition (42). When enteral nutrition is performed, the nutrients entering the intestine can promote the recovery of intestinal blood supply, improve the high catabolic response of the body, reduce the release of inflammatory mediators, promote anabolic and intestinal environment recovery as soon as possible, and, finally, protect the intestinal mucosal barrier (12), avoiding the destruction of the intestinal mucosal barrier, which leads to gastrointestinal complications such as bleeding peptic ulcer, destruction of immune function, and translocation of intestinal flora. Therefore, the nutritional support strategy can be optimized in terms of the nutrition start time, calorie supply, and adjustment after the emergence of complications.

The gastrointestinal tract gradually resumes function 2 hours after abdominal surgery, whereas it should be restored 24 hours after extracorporeal circulation (27). Some studies first started enteral nutritional support 6 hours after cardiac surgery (43,44). In this study, we considered that myocardial edema started to appear at 8 hours after surgery in high-risk patients, and the addition of enteral nutrition at this time may lead to an increased functional load on the heart and the gastrointestinal tract (45), so we started enteral nutrition support at 12 hours after surgery when the patient was hemodynamically stable. Table 4 shows that patients in the EN group had significantly higher nutritional parameters at 7 days postoperation than those in the TN group. The significant difference in prealbumin levels ($P < 0.001$) reflects the fact that the optimized nutritional support strategy not only improves the nutritional level in the short term postoperatively but also increases the nutritional reserve of the patients. The significant increase in postoperative hemoglobin in the EN group also suggested that adequate nutritional support could improve the patient's anemia status and significantly improve the long-term heart failure wasting status of high-risk patients.

The polymeric immunoglobulin secreted by the intestinal mucosal system is mainly IgA, which plays an important role in the prevention of gastrointestinal infection and the local anti-infection of the mucosa (46,47). Table 4 shows that the immune index IgA of the patients in the EN group was higher than that in the TN group, suggesting that early enteral nutrition support can support both activities. The first is the enhancement of nutrient reserves and immunoglobulins (mainly IgA) through enteral nutrition. Immunoglobulins reshape bacterial communities by reducing the immunogenicity of bacteria or sequestering bacteria in the mucus layer, and then the human immune system acquires immune complexes (48), which ultimately prevent dysbiosis and infection in the gastrointestinal tract. Second, the gradual enhancement of enteral nutrition by Slight Liquid Diet, Peptisorb, and ordinary diet plus homogenate diet will not only protect the gastrointestinal mucosa, ensuring that the gastrointestinal mucosa plays its normal anti-infective role, but also avoid placing a severe burden on the gastrointestinal tract.

The diagnosis of gastrointestinal complications after cardiac surgery is difficult, and in-hospital mortality increases when severe gastrointestinal complications occur (49–51). Our study included common gastrointestinal complications such as diarrhea, abdominal distension, vomiting, and gastrointestinal bleeding. Table 5 shows that the incidence of postoperative gastrointestinal complications in the EN group was significantly lower than that in the TN group. The reduction of common complications such as diarrhea and abdominal distension suggests that early enteral nutrition support can promote the recovery of gastrointestinal motility in patients. Although there was no significant difference in the incidence of vomiting and gastrointestinal bleeding between the two groups, the incidence of these two gastrointestinal complications in the EN group was lower than those in the TN group. The lower incidence of nosocomial pulmonary infection in patients in the EN group also suggests that patients in the EN group can reduce the systemic inflammatory response caused by gastrointestinal flora imbalance under more optimized nutritional support. Moreover, sufficient energy and protein supply after surgery

Table 4. **Differences in nutrition and immunity levels on postoperative day 7**

Variable	EN group (N = 193)	TN group (N = 185)	*P*
Prealbumin (mg/L)	188.0 (162.0, 216.0)	159.0 (139.0, 181.5)	0.001
Albumin (g/L)	42.0 (37.0, 46.0)	34.0 (31.0, 36.0)	0.001
Total protein (g/L)	64.5 (59.0, 72.0)	61.0 (55.0, 68.0)	0.001
Globulin (g/L)	28.0 (25.0, 32.0)	27.0 (23.0, 31.0)	0.001
Hemoglobin (g/L)	116.0 (100.0, 128.8)	98.0 (85.0, 109.0)	0.001
IgA (g/L)	2.9 (2.0, 4.5)	2.2 (1.78, 3.21)	0.001
IgG (g/L)	15.5 (12.7, 18.1)	14.3 (11.35, 18.3)	0.110
IgM (g/L)	1.36 (0.98, 1.52)	1.23 (0.81, 1.45)	0.010

Significant difference, $P < 0.05$.
EN, optimized enteral nutritional support strategy; TN, traditional nutritional support strategy.

Table 5. **Gastrointestinal complications in patients on postoperative day 7**

Variable	EN group (N = 193)	TN group (N = 185)	*P*
GI complications	14 (7.3%)	26 (14.1%)	0.032
Diarrhea	8 (4.1%)	19 (10.3%)	0.021
Abdominal distension	11 (5.7%)	22 (11.9%)	0.033
Vomit	10 (5.2%)	19 (10.3%)	0.063
GIB	5 (2.6%)	9 (4.9%)	0.242
OB(+)	4 (2.1%)	7 (3.8%)	0.322
OB(++~)	1 (0.5%)	2 (1.1%)	0.971

Significant difference, $P < 0.05$.
GI complications, gastrointestinal complications; EN, optimized enteral nutritional support strategy; TN, traditional nutritional support strategy; GIB, Gastrointestinal bleeding.

Table 6. **The covariate Poisson regression of complications**

Variable	RR	95% CI	*P*
CPBT (min)	1.001	0.993–1.009	0.782
ACCT (min)	0.994	0.983–1.006	0.346
Ventilator duration (h)	1.004	1.001–1.007	0.007
ICU duration (h)	1.007	1.004–1.009	0.001
EN	1.218	0.639–2.321	0.549

CPBT, cardiopulmonary bypass time; ACCT, aortic occlusion time.

can reduce skeletal muscle catabolism, maintain inspiratory muscle strength, shorten the duration of ventilator use, and allow patients to cough and expectorate more vigorously. Therefore, patients are able to undergo bedside rehabilitation as soon as possible, thereby reducing the incidence of atelectasis and hypostatic pneumonia (52).

Limitations

This study still had some limitations. First, it was a single-center retrospective study, and the data may have been biased due to the small sample size of this study; thus, prospective, multicenter studies are needed to confirm our conclusions. Second, we did not evaluate the effect of postoperative vasoactive drug use and other factors on nutritional tolerance and the occurrence of digestive system complications. Third, we have not conducted a long-term follow-up of patients who have been discharged from hospital, so survival analysis cannot be carried out to explore whether optimized nutritional support can improve the long-term survival rate and improve the long-term prognosis of patients.

CONCLUSION

In conclusion, this study suggests that early enteral nutrition support may not reduce hospital mortality. However, it may reduce hospital-acquired pneumonia, shorten the length of hospital stay, and reduce overall hospital costs. These results suggest that early enteral nutrition provides some degree of clinical benefit to high-risk patients undergoing cardiac surgery. However, further studies are needed to validate the results of this study.

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