Title page

Title: Feeding intolerance and risk of poor outcome in patients undergoing cardiopulmonary bypass surgery

Author names: Yanjuan Lin¹ ‡, Meihua Chen³ ‡, Yanchun Peng², Qiong Chen², Sailan Li³, Liangwan Chen³ *

Author affiliations:
1 Department of Nursing, Fujian Medical University Union Hospital, 29 Xinquan Road, Fuzhou City, Fujian Province, China
2 Fujian Medical University, 88 Jiaotong Road, Fuzhou City, Fujian Province, China
3 Department of Cardiac Surgery, Fujian Medical University Union Hospital, 29 Xinquan Road, Fuzhou City, Fujian Province, China

* Corresponding author:
Yanjuan Lin, mailing address: Department of Nursing, Fujian Medical University Union Hospital, 29 Xinquan Road, Fuzhou City, Fujian Province, China; E-mailing address: fjsxhyjl@163.com; telephone numbers: 086+0591-83357896

Liangwan Chen, mailing address: Department of Cardiac Surgery, Fujian Medical University Union Hospital, 29 Xinquan Road, Fuzhou City, Fujian Province, China; E-mailing address: chenliangwan@tom.com; telephone numbers: 086+0591-83357896

‡ Authors contributed equally

Abbreviated title: Poor outcome risk of cardiopulmonary bypass

Keywords: Cardiopulmonary bypass, enteral nutrition, feeding intolerance, poor prognosis

This peer-reviewed article has been accepted for publication but not yet copyedited or typeset, and so may be subject to change during the production process. The article is considered published and may be cited using its DOI 10.1017/S0007114521000167

The British Journal of Nutrition is published by Cambridge University Press on behalf of The Nutrition Society
Feeding intolerance and risk of poor outcome in patients undergoing cardiopulmonary bypass surgery

Abstract

We conducted a prospective, observational study to determine the incidence of feeding intolerance (FI) within seven days of initiating enteral nutrition (EN) in patients undergoing cardiopulmonary bypass (CPB), and to evaluate the association between FI and a poor prognosis. Patients who underwent CPB surgery at Fujian Medical University Union Hospital between March 2020 and June 2020 were enrolled. According to the presence or absence of FI within seven days after EN, patients were divided into FI and non-FI groups. According to the occurrence of a poor prognosis (death, gastrointestinal haemorrhage, acute kidney injury, liver insufficiency, neurological events [cerebral infarction, cerebral haemorrhage, epilepsy], and prolonged mechanical ventilation [>48 hours]), patients were divided into poor prognosis and good prognosis groups. The mean (standard deviation) age of the 237 CPB patients, including 139 men and 98 women, was 53.80 ± 12.25 years. The incidence of FI was 64.14%. There were 152 cases in the FI group and 85 cases in the non-FI group. Multivariate logistic regression analysis showed factors independently associated with poor prognosis after CPB included FI (odds ratio [OR], 2.138; 95% confidence interval [CI], 1.058–4.320), age (OR, 1.033; 95% CI, 1.004–1.063), NYHA class III - IV cardiac function (OR, 2.410; 95% CI, 1.079–5.383), macrovascular surgery (OR, 5.434; 95% CI, 1.704–17.333), and initial sequential organ failure assessment score (OR, 1.243; 95% CI, 1.010–1.530). Thus, the incidence of FI within seven days of EN after CPB was high, which was associated with a poor prognosis.
Introduction

The 2019 guidelines on enteral nutrition (EN) by the European Society for Clinical Nutrition and Metabolism (ESPEN) state that patients who can fully adapt to EN and have strong recovery ability should receive EN \(^{(1)}\). However, feeding intolerance (FI) during EN, especially after cardiopulmonary bypass (CPB), can impact nutritional support programmes significantly \(^{(2)}\).

During CPB, redistribution of blood flow to critical body organs, such as the brain, results in earlier reduction in blood flow to abdominal organs. Moreover, other factors, such as haemodilution, cause the gastrointestinal tract to be in a state of low perfusion and hypoxia, which leads to functional gastrointestinal injury \(^{(3,4)}\).

FI is the most common clinical manifestation of functional gastrointestinal injury; a higher incidence of gastrointestinal functional injury is associated with a higher incidence of FI \(^{(5,6)}\). According to the literature, the incidence of FI in critically ill patients during EN is between 30.5\% and 65.7\%, which causes critically ill patients to fail to meet their nutritional goals, prolongs the duration of mechanical ventilation, and increases the length of stay at the intensive care unit (ICU) \(^{(2,7)}\). A case–control retrospective study reported that FI within three days of admission to the neurological ICU was an independent predictor of poor prognosis in patients with severe neurological diseases \(^{(8)}\). The contribution of malnutrition to a poor prognosis has increasingly attracted the attention of medical practitioners. Current research has, however, focused mainly on FI in critically ill patients after non-cardiac surgery and premature infants, with relatively fewer reports on the incidence of FI and whether FI affects the prognosis in CPB patients. Therefore, we aimed to determine the incidence of FI and to investigate whether FI is associated with a poor prognosis in CPB patients.
Experimental methods

Participants and study design

In this prospective, observational study, CPB patients aged >18 years admitted to the Fujian Medical University Union Hospital from March 2020 to June 2020 were included. According to the definition of FI, whereby 1 or more of the following features are present: large gastric residual volume (GRV), abdominal distension; vomiting; diarrhoea or constipation (2), patients were divided into FI and non-FI groups. Patients with an ICU duration of stay of <24 hours, gastrointestinal tumours, chronic diarrhoea, total intestinal obstructions, gastrointestinal resections on admission, and in whom the initial enteral nutrition time was longer than 48 hours after operation and patients with serious mental illnesses were excluded from the study.

All patients received appropriate fluid resuscitation and ventilation therapy. Routine conditions for enteral nutrition include: a semi-decubitus position between 30–45°. Patients were assigned to receive either a nasogastric tube EN or an oral EN. Oral intake was performed based on the patient having removed the endotracheal tube and no swallowing disturbance, the gastric tube was indwelling at the bedside, and the position of the gastric tube was determined by the sound of air and water and PH. Gastrointestinal motility drugs were added when the gastric residual amount was more than 200 ml or when abdominal distension occurred. When the patient was constipated, laxative treatment was administered; when the patient had diarrhoea, antidiarrheal treatment was administered. According to our ICU mechanical ventilation guidelines, all patients receive the same care. When the extubation standard was reached, mechanical ventilation of the patient ceased.

Ethical approval

This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects/patients were approved by the
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ethics committee of the Fujian Medical University Union Hospital (ethics number: 2020KY014). Written informed consent was obtained from all participants.

Variables and data collection

A data collection table was designed by the researchers. Partial data were prospectively collected by a stationary researcher using the hospital clinical electronic database. Data collected included demographic characteristics (age, sex, body mass index [BMI], education level, marital status, lifestyle [smoking and alcohol history], and past medical history [hypertension, diabetes, cerebral infarction]). The clinical data included preoperative data (New York Heart Association [NYHA] cardiac functional classification), intraoperative data (type of cardiac surgery, operation time, CPB time, and aortic clamping time), postoperative data (sequential organ failure assessment [SOFA] score on the first day after surgery, the highest VIS score within 24 hours after surgery, the highest lactic acid score within 24 hours after surgery, the MAP within 24 hours after surgery, duration of mechanical ventilation, length of ICU and hospital stay), relevant data on FI (vomiting, gastric residual volume, diarrhoea, abdominal distension, constipation), and EN-related data (type, quantity, mode).

Outcome indicators

The main outcome indicators were death during hospitalisation, postoperative complications, including gastrointestinal haemorrhage, acute kidney injury, liver insufficiency, neurological events (cerebral infarction, cerebral haemorrhage, and epilepsy), and long-term mechanical ventilation.

Definition of variables

FI within seven days after EN: The patient had one or more of the following symptoms within seven days after receiving EN, including vomiting, diarrhoea, abdominal distension, constipation, or large gastric residues (2). Vomiting was defined as the reflux of any visible gastrointestinal content regardless of the amount of vomit
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(except vomiting due to mechanical movement of the endotracheal tube and nasogastric tube). Diarrhoea was defined as an increase in faecal moisture and stool frequency; frequency of defecation >3 times/day or faecal volume >200 g/day. A large GRV was defined as a single gastric residue withdrawal of >200 ml. Abdominal distension was defined as abdominal distension or fullness discomfort, which could be subjective. Liver insufficiency was defined as a peak serum total bilirubin level of >7 mg/dl after surgery \(^9\). Prolonged mechanical ventilation was defined as ventilation for \(\geq 48\) hours \(^10\). According to The Kidney Disease: Improving Global Outcomes (KDIGO) criteria, AKI was defined as any of the following: an increase in serum creatinine(SCR) by \(\geq 0.3\) mg/dl (\(\geq 26.5\) µmol/L) within 48 hours; or increase in SCR to \(\geq 1.5\) times baseline level within seven days after surgery; or urine volume < 0.5 ml/kg/h for 6 hours \(^11\). Poor prognosis was defined as the occurrence of gastrointestinal haemorrhage, acute kidney injury, liver insufficiency, neurological events (cerebral infarction, cerebral haemorrhage, and epilepsy), or prolonged mechanical ventilation.

The SOFA score used the worst value of each parameter within 24 hours of the operation. The VIS score and lactic acid value were the highest values within 24 hours after surgery. For the calculation of the vascular active drug usage peak 24 hours after surgery reports, the Gaies \(^12\) formula for the determination of the VIS value was used: \(\text{VIS} = \text{dopamine} \left( \mu \text{g kg}^{-1} \text{ min}^{-1} \right) + \text{dobutamine} \left( \mu \text{g kg}^{-1} \text{ min}^{-1} \right) + 10 \times \text{milrinone} \left( \mu \text{g kg}^{-1} \text{ min}^{-1} \right) + 100 \times \text{adrenaline} \left( \mu \text{g kg}^{-1} \text{ min}^{-1} \right) + 100 \times \text{norepinephrine} \left( \mu \text{g kg}^{-1} \text{ min}^{-1} \right) + 10000 \times \text{pituitrin} \left( \text{U kg}^{-1} \text{ min}^{-1} \right)\). All vasoactive drugs were continuously pumped through a micropump.

**Statistical analyses**

All data were analysed using SPSS 25.0 statistical software (SPSS Inc., Chicago, IL, USA). Normally distributed data were described as means \(\pm\) standard deviations, and the group t-test was used for comparison between groups. Non-normally distributed
data were represented by medians and interquartile ranges (M [P25, P75]), and the rank sum test was used for comparison between the groups. The count data were described by frequencies and percentages; the chi-square test or Fisher’s exact test was used for comparison between groups. Univariate logistic regression analysis was used to identify risk factors associated with poor prognosis, and multivariate logistic regression analysis was conducted to determine significant risk factors. P-values <0.05 were considered statistically significant.

Results

Selection of participants

The inclusion of participants in the study is summarised in Figure 1. Of the 302 patients enrolled from March 1, 2020 to June 30, 2020, after applying the exclusion criteria, 237 were included in the analysis. There were 152 patients in the FI group and 85 in the non-FI group. The incidence of FI was 64.14%.

Demographic and clinical characteristics of patients with and without FI

Tables 1 and 2 show the demographic and clinical characteristics of patients in the two groups. The mean age of the 237 CPB patients, including 139 men (58.6%) and 98 women (41.4%), was 53.80 ± 12.25 years. The mean SOFA score of the study participants was 11.82 ± 1.914. Compared with the non-FI group, the FI group had a significantly longer operation time (251 minutes vs. 221 minutes, P=0.014), CPB time (122 minutes vs. 101 minutes, P=0.001), aortic clamping time (62.5 minutes vs. 52 minutes, P=0.023) and length of hospital stay (20 days vs. 18 days, P=0.020).

Comparison of poor prognosis between the FI and non-FI groups

As shown in Table 3, compared with the non-FI group, the FI group had a significantly higher proportion of patients on prolonged mechanical ventilation (>48 hours) (OR, 2.627; 95% CI, 1.098–6.288), acute kidney injury rate (OR, 2.569; 95% CI,
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1.242–5.310), and neurological events rate (OR, 7.856; 95% CI, 1.009–61.142). The comprehensive incidence of postoperative complications in the FI group was also higher (OR, 2.233; 95% CI, 1.207–4.132).

Univariate and multivariate comparisons of the poor prognosis group

The baseline clinical characteristics of patients with a poor prognosis are shown in Table 4. The age (OR, 1.040; 95% CI, 1.015–1.066), Cerebral infarction (OR, 3.725; 95% CI, 1.176–11.806), NYHA functional class III/IV (OR, 2.660; 95% CI, 1.349–5.243), macrovascular surgery (OR, 3.565; 95% CI, 1.450–8.764), operation time (OR, 1.007; 95% CI, 1.003–1.011), CPB time (OR, 1.008; 95% CI, 1.003–1.013), SOFA score (OR, 1.445; 95% CI, 1.234–1.693), FI (OR, 2.233; 95% CI, 1.207–4.132), and the highest VIS score within 24 hours after surgery (OR, 1.034; 95% CI, 1.008–1.062), the highest lactic acid score within 24 hours after surgery (OR, 1.109; 95% CI, 1.026–1.198) were associated with a poor prognosis. The multivariate logistic regression analysis of poor prognosis showed that after adjusting for cerebral infarction, operating time and CPB time, the highest VIS and highest lactic acid scores within 24 hours after surgery, FI (OR, 2.138; 95% CI, 1.058–4.320; P=0.034), age (OR, 1.033; 95% CI, 1.004–1.063; P=0.026), NYHA functional class III/IV (OR, 2.410; 95% CI, 1.079–5.383; P=0.032), macrovascular surgery (OR, 5.434; 95% CI, 1.704–17.333; P=0.004), and SOFA score (OR, 1.243; 95% CI: 1.010–1.530; P=0.040) retained statistical significance, indicating that these variables were predictors of poor prognosis after CPB.

Discussion

This study is the first prospective, observational study to evaluate the correlation between FI and poor prognosis in patients undergoing CPB surgery. The results showed that: (1) the incidence of FI after CPB was 64.14%; (2) FI was significantly associated with prolonged mechanical ventilation (>48 hours), acute kidney injury, and neurological events in patients after CPB; and (3) FI, SOFA score, age, NYHA
Functional class III/IV and macrovascular surgery were independent predictors of poor prognosis after CPB. Therefore, for patients with EN after CPB, assessing FI can help identify patients at risk of poor prognosis.

The systematic review by Blaser et al. showed that the incidence of FI was 30.5%–65.7% in critically ill patients and was higher (50.0%–88.9%) in mechanically ventilated patients \(^{(13)}\). In this current study, the incidence of FI within 7 days of EN in CPB patients was 64.14%; the incidence of constipation was high (44.7%; 106 cases) and the incidence of abdominal distension was low (11.4%; 27 cases). During CPB, the redistribution of blood flow to critical body organs, such as the brain, results in an earlier reduction in blood flow to abdominal organs. Moreover, other factors, such as haemodilution, cause the gastrointestinal tract to be in a state of low perfusion and hypoxia, which leads to functional gastrointestinal injury \(^{(14)}\). Furthermore, in this current study, all the patients underwent mechanical ventilation after CPB. A study \(^{(15)}\) has shown that mechanical ventilation can cause bile reflux and gas to enter the stomach, with increased intra-abdominal pressure leading to gastrointestinal dysfunction. Therefore, FI, as the most common clinical manifestation of functional gastrointestinal injury, is easy to occur during the implementation of EN after CPB.

Another significant finding in this study was the association of FI with poor prognosis in CPB patients. A case–control study \(^{(8)}\) on severe neurological diseases found that FI within 3 days of ICU admission was independently associated with poor prognosis in patients with severe neurological diseases. Gungabissoon et al. \(^{(2)}\) reported that EN FI in critically ill patients was associated with failed nutritional goals, prolonged duration of mechanical ventilation, increased number of hospitalisation days, and 60-day mortality. This current study found that FI was significantly related to a poor prognosis of patients after CPB (OR, 2.138; 95% CI, 1.058-4.320). According to recent research, >45% of nurses immediately stopped EN when FI was present \(^{(16)}\), resulting in reduced energy and protein intake of 1780.23 kcal and 100.58 g, respectively \(^{(17)}\). Thus, it can be seen that the frequency of EN in patients with FI decreases, or even interrupts feeding, thus leading to nutritional deficiency, which impacts patient prognosis. Poor nutritional status can significantly affect intestinal
epithelial cell renewal (proliferation, migration, differentiation, and apoptosis) and intestinal barrier function\(^{(18)}\), which may lead to impaired digestion and absorption of nutrients, as well as atrophy of lymphoid tissue, decline of immune system function, and an aggravation of intestinal bacterial translocation\(^{(19,20)}\). Because of impaired intestinal barrier function and bacterial translocation, the intestinal epithelium and lung epithelium are exposed to high concentrations of foreign antigens, forming the centre for the initiation and maintenance of an inflammatory response, which may lead to or aggravate multiple organ damage or failure\(^{(21)}\).

SOFA score is significantly associated with a poor prognosis in patients undergoing CPB. The SOFA score is a scoring system used to evaluate multiple organ dysfunction or failure in ICU patients, and is based on the PaO\(_2\)/FiO\(_2\) ratio, platelet count, bilirubin level, cardiovascular hypotension, nervous system status, and renal function. A prospective study of 857 cardiac ICU patients\(^{(22)}\) found that the SOFA score was an independent predictor of mortality and hospital stay in patients undergoing cardiac surgery. Moreover, in the early assessment after adult cardiac surgery, the SOFA score was related to morbidity and mortality; the SOFA score on the first day after surgery can predict the 30-day mortality rate\(^{(22)}\). In this study, the multifactor analysis showed that the SOFA score was an independent risk factor for a poor postoperative prognosis of CPB patients (OR, 1.243; 95% CI, 1.010–1.530), which was consistent with the results of previous studies. The incidence of prolonged mechanical ventilation in our study population (>48 hours) was 15.2%; acute kidney injury 22.4%, neurological events 5.9%, and death 3.0%. Compared with data from the Adult Cardiac Surgery Database of the National Association of Thoracic and Cardiac Surgeons in the United States\(^{(23)}\), the mortality and prolonged mechanical ventilation (>48 hours) rate in this study is comparable, but the incidence of acute neurological damage is higher, which may be related to the study population that included patients who had macrovascular surgery. Therefore, in clinical work, patients with high SOFA scores should be closely observed for the function of each organ, and corresponding measures should be taken to reduce the incidence of poor prognosis.
Age and NYHA functional class III/IV were significantly associated with poor prognosis in patients undergoing cardiopulmonary bypass. Thorsteinsson et al. studied 38,830 patients who underwent coronary artery bypass surgery alone and found that with the increase of operation age, the burden of comorbidities increases, and age is the main predictor of 30-day mortality after surgery. An international study found that the mortality rate of type A aortic dissection after surgery increased significantly with age, and age over 70 was an independent predictor of postoperative mortality. At the same time, age is also an influential factor of FI. A previous study has shown that age is also an influential factor for FI in EN patients. Our study also found that the age in the FI group was significantly higher than that in non-FI group (54.26 ± 11.907 vs 52.98 ± 12.863). In addition, a study of 638 patients over 80 years of age after aortic valve replacement found that NYHA functional class III/IV was an independent predictor of hospital mortality. In this study, the multivariate analysis showed that age (OR, 1.033; 95% CI, 1.004–1.063) and NYHA functional class III/IV (OR, 2.410; 95% CI, 1.079–5.383) were independent risk factors for poor prognosis in patients with CPB, which was consistent with previous studies. Studies have shown that with age, the cardiovascular system presents progressive structural and functional changes, especially with regards to the decrease in the number of myocardial cells and the increase in interstitial collagen fibres, resulting in impaired left ventricular diastolic function and decreased cardiac function. At the same time, the burden of comorbidities increases due to the decline in the functional reserve of various organs in elderly patients. In addition, with the increase of age, jejunal villi become sparse and thick, and the mucosa gradually shrinks, resulting in an increase in the incidence of FI after enteral nutrition. Therefore, we should pay close attention to the occurrence of FI in elderly patients with NYHA functional class III/IV in clinical work and take corresponding measures in time to reduce the incidence of adverse prognosis.

The results of this current study should be interpreted considering the following limitations. First, this project was a single-centre prospective study with a small sample size. A multicentre prospective cohort study with a large sample size is
recommended to further verify the predictive value of FI on poor prognosis in CPB patients. Second, we only analysed the results of hospitalised patients and did not follow-up patients after discharge. Therefore, we were unable to determine the long-term effect of FI on poor prognosis indicators in patients who had CPB.

Conclusion

In this study, FI within 7 days of initiating EN was associated with a poor prognosis (death, gastrointestinal haemorrhage, acute kidney injury, liver insufficiency, nervous system events [cerebral infarction, cerebral haemorrhage, and epilepsy], and prolonged mechanical ventilation [>48 hours]) in CPB patients. These results highlight the need for clinicians to focus more on early FI after CPB. However, these results need to be verified in larger prospective studies.

Acknowledgements

We want to thank all the participants and their relatives on the study.

Financial support

This work was supported by the Promotion project for appropriate Technology of the Health Committee, Fujian province (Grant number: 2019018) and the Joint Finds for the Innovation of Science and Technology, Fujian province (Grant number: 2017Y9052).

Conflict of interest

None.

Authorship

Y. L., M. C., Y. P., Q. C., S. L. and L. C. designed the research; M. C. was responsible for trial execution and data collection under the supervision of Y. L., Y. P., Q. C., S. L. and L. C.; S. L. and L. C. provided access to potential study participants and facilitated study recruitment; Q. C. analysed data; M. C. wrote the first draft of the manuscript, which was critically reviewed and improved by all authors. Y. L. and L. C. had the primary responsibility for the final content. All the authors have read and approved the final manuscript.
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Table 1. Comparison of baseline data between the FI and non-FI groups

| Variable                  | Total (N=237) | Non-FI group (N=85) | FI group (N=152) | P-value |
|---------------------------|---------------|---------------------|------------------|---------|
|                           | N  | %   | N   | %   | N   | %   |       |
| **Demographic factors**   |    |     |     |     |     |     |       |
| Age, years                |    |     |     |     |     |     | 0.441 |
| mean                      |    |     |     |     |     |     |       |
|                           | 53.80 |      | 52.98 |      | 54.26 |      | 0.441 |
| SD                        |    |     |     |     |     |     |       |
|                           | 12.25 |      | 12.86 |      | 11.91 |      |       |
| Sex, male                 |    |     |     |     |     |     | 0.157 |
|                           | 139 | 58.65 | 55 | 64.7 | 84 | 55.2 |       |
| BMI, kg/m²                |    |     |     |     |     |     | 0.348 |
| mean                      |    |     |     |     |     |     |       |
|                           | 22.86 |      | 22.62 |      | 22.99 |      | 0.348 |
| SD                        |    |     |     |     |     |     |       |
|                           | 3.14  |      | 2.66  |      | 3.38  |      |       |
| **Education level**       |    |     |     |     |     |     | 0.721 |
| Primary schools and below |    |     |     |     |     |     |       |
|                           | 135 | 56.96 | 50 | 58.8 | 85 | 55.9 |       |
| Middle school             |    |     |     |     |     |     |       |
|                           | 50  | 21.1  | 16 | 18.8 | 34 | 22.4 |       |
| High school or technical  |    |     |     |     |     |     |       |
| secondary school          |    |     |     |     |     |     |       |
|                           | 32  | 13.5  | 14 | 16.5 | 18 | 11.8 |       |
| Junior college or above   |    |     |     |     |     |     |       |
|                           | 20  | 8.44  | 5  | 5.9  | 15 | 9.8  |       |
| Smoker                    |    |     |     |     |     |     | 0.625 |
|                           | 63  | 26.6  | 21 | 24.7 | 42 | 27.6 |       |
### Drinker

|      |     |     |     |     |     |     |
|------|-----|-----|-----|-----|-----|-----|
|      | 8   | 3.4 | 4   | 4.7 | 4   | 2.6 |
|      | 0.462<sup>a</sup> |

### Marital status

|      |     |     |     |     |     |     |
|------|-----|-----|-----|-----|-----|-----|
|      | 232 | 97.9| 82  | 96.5| 150 | 98.7|
|      | 0.353<sup>a</sup> |

**Past medical history**

|      |     |     |     |     |     |     |
|------|-----|-----|-----|-----|-----|-----|
|      | 60  | 25.3| 23  | 27.1| 37  | 24.3|
|      | 0.645 |

|      | 14  | 5.9 | 6   | 7.1 | 8   | 5.3 |
|      | 0.583 |

|      | 13  | 5.5 | 2   | 2.4 | 11  | 7.3 |
|      | 0.143<sup>a</sup> |

<sup>a</sup> Fisher’s exact test.

FI, feeding status; SD, standard deviation; BMI, Body Mass Index.
Table 2. Comparison of clinical data between the FI and non-FI groups

| Variable                        | Total (N=237) | Non-FI group (N=85) | FI group (N=152) | P-value |
|---------------------------------|---------------|---------------------|------------------|---------|
|                                 | N  | %    | N  | %    | N  | %    |       |
| **Preoperative factors**        |    |       |    |       |    |       |       |
| NYHA functional class III/IV    | 166| 70.0  | 59 | 69.4  | 107| 70.4  | 0.874 |
| **Intraoperative factors**      |    |       |    |       |    |       |       |
| Macrovascular surgery           | 22 | 9.3   | 10 | 11.8  | 12 | 7.9   | 0.325 |
| Operating time, minutes         |    |       |    |       |    |       | 0.014 |
| median                          | 240.00 |       | 221.0 |       | 251.0 |       |       |
| IQR                             | 202.50–304.50 |       | 182.5–286.0 |       | 211.3–314.3 |       |       |
| CPB time, minutes               |    |       |    |       |    |       | 0.001 |
| median                          | 116.0 |       | 101.0 |       | 122.0 |       |       |
| IQR                             | 83.50–159.50 |       | 68.0–141.05 |       | 93.0–163.8 |       |       |
| Aortic clamping time, minutes   |    |       |    |       |    |       | 0.023 |
| median                          | 60.0 |       | 52.0 |       | 62.5 |       |       |
| IQR                             | 35.0–92.50 |       | 30.0–84.0 |       | 40.3–99.3 |       |       |
| **Postoperative factors**       |    |       |    |       |    |       |       |
| Length of hospital stay, days | 0.020 |
|-----------------------------|-------|
| median                      | 19.0  |
| IQR                         | 15.0–24.0 |
| Length of ICU stay, hours   | 0.171 |
| median                      | 46    |
| IQR                         | 39.0–70.0 |
| Mechanical ventilation time, hours | 0.206 |
| median                      | 20    |
| IQR                         | 16.0–38.5 |
| SOFA score                  | 0.168 |
| mean                        | 11.82 |
| SD                          | 1.91  |
| Feeding patterns            | 0.982 |
| Oral feeding                |       |
|                             | 195   |
|                             | 82.3  |
|                             | 70    |
|                             | 82.4  |
|                             | 125   |
|                             | 82.2  |
| Nasogastric feeding         |       |
|                             | 42    |
|                             | 17.7  |
|                             | 15    |
|                             | 17.6  |
|                             | 27    |
|                             | 17.8  |
| VIS<sub>max</sub>           | 0.057 |
| median                      | 10    |
|                             | 10    |
|                             | 10.5  |
|            | IQR          | Median | IQR          |
|------------|--------------|--------|--------------|
| Lactic acid_{max} | 9-13         | 4.45   | 4.1          | 4.6          |
|             | 8-12         |        | 2.7-6.2      | 2.95-6.895   |
| MAP        | 10-14.4      |        |              |              |
|            | 0.375        |        |              |              |
| median     | 84           | 82     | 84.67        |
| IQR        | 75.33-93.5   | 74.83-96.33 | 77.08-93.33 |

FI, feeding intolerance; NYHA, New York Heart Association; IQR, interquartile range; CPB, cardiopulmonary bypass; ICU, intensive care unit; SOFA, sequential organ failure assessment; SD, standard deviation; VIS, Vasoactive-inotrop score. MAP, mean arterial pressure.
Table 3. Comparison of poor prognosis between the FI and non-FI groups

| Variable                                | Non-FI group (N=85) | FI group (N=152) | OR   | 95% CI     | P-value |
|-----------------------------------------|---------------------|------------------|------|------------|---------|
|                                          | N   | %    | N   | %    |         |         |
| Prolonged mechanical ventilation (>48 hours) | 7   | 8.2  | 29  | 19.1 | 2.627   | 1.098-6.288 | 0.030 |
| Acute kidney injury                      | 11  | 12.9 | 42  | 27.6 | 2.569   | 1.242-5.310 | 0.011 |
| Liver insufficiency                      | 3   | 3.5  | 5   | 3.3  | 0.930   | 0.217-3.990 | 0.922 |
| Death                                   | 1   | 1.2  | 6   | 3.9  | 3.452   | 0.409-29.164 | 0.255 |
| Neurological events a                    | 1   | 1.2  | 13  | 8.6  | 7.856   | 1.009-61.142 | 0.049 |
| Gastrointestinal haemorrhage            | 1   | 1.2  | 6   | 3.9  | 3.452   | 0.409-29.164 | 0.255 |
| Overall poor prognosis                   | 18  | 21.2 | 57  | 37.5 | 2.233   | 1.207-4.132 | 0.010 |

FI, feeding status; OR, odds ratio; CI, confidence interval.

a cerebral infarction, cerebral haemorrhage, epilepsy.
Table 4. Univariate and multivariate comparison of the poor prognosis group after CPB

| Variable                        | Univariate analysis |                      |                      |
|---------------------------------|---------------------|----------------------|----------------------|
|                                 | OR                  | 95% CI               | OR                  |
| Demographic factors             |                     |                      |                      |
| Age                             | 1.040               | 1.015-1.066          | 1.033               |
|                                 |                     |                      | 1.004-1.063          |
| Sex, male                       | 0.922               | 0.528-1.609          | –                   |
|                                 |                     |                      | –                   |
| BMI                             | 1                   | 0.916-1.091          | –                   |
|                                 |                     |                      | –                   |
| Smoker                          | 1.484               | 0.811-2.716          | –                   |
|                                 |                     |                      | –                   |
| Marital status                  | 1.452               | 0.238-8.877          | –                   |
|                                 |                     |                      | –                   |
| Past medical history            |                     |                      |                      |
| Hypertension                    | 1.355               | 0.732-2.507          | –                   |
|                                 |                     |                      | –                   |
| Diabetes                        | 1.232               | 0.398-3.812          | –                   |
|                                 |                     |                      | –                   |
| Cerebral infarction             | 3.725               | 1.176-11.806         | 2.726               |
|                                 |                     |                      | 0.759-9.785          |
| Preoperative factors            |                     |                      |                      |
| NYHA functional class III/IV    | 2.660               | 1.349-5.243          | 2.410               |
|                                 |                     |                      | 1.079-5.383          |
| Intraoperative factors          |                     |                      |                      |
| Macrovascular surgery           | 3.565               | 1.450-8.764          | 5.434               |
|                                 |                     |                      | 1.704-17.333         |
| Operating time                  | 1.007               | 1.003-1.011          | 1.001               |
|                                 |                     |                      | 0.993-1.009          |
| CPB time                        | 1.008               | 1.003-1.013          | 1.001               |
|                                 |                     |                      | 0.991-1.011          |
| Aortic cross clamp time         | 1.003               | 0.997-1.009          | –                   |
|                                 |                     |                      | –                   |
| Postoperative factors           |                     |                      |                      |
| SOFA score                      | 1.445               | 1.234-1.693          | 1.243               |
|                                 |                     |                      | 1.010-1.530          |
| FI                              | 2.233               | 1.207-4.132          | 2.138               |
|                                 |                     |                      | 1.058-4.320          |
| VIS<sub>max</sub>               | 1.034               | 1.008-1.062          | 1.012               |
|                                 |                     |                      | 0.980-1.045          |
| Lactic acid<sub>max</sub>       | 1.109               | 1.026-1.198          | 1.002               |
|                                 |                     |                      | 0.910-1.104          |
| MAP                             | 1.000               | 0.984-1.016          | –                   |
|                                 |                     |                      | –                   |
| anticoagulant therapy           | 0.605               | 0.308-1.190          | –                   |
|                                 |                     |                      | –                   |

OR, odds ratio; CI, confidence interval; BMI, Body Mass Index; NYHA, New York Heart Association; CPB, cardiopulmonary bypass; SOFA, sequential organ failure assessment; FI, feeding intolerance; VIS, Vasoactive-inotrop score. MAP, mean arterial pressure.