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ORIGINAL RESEARCH

The Effects of Endoscopy-Guided Nasojejunal Feeding Tube Placement in Post-COVID-19 ICU Patients: A Retrospective Study

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Background: The impact of complications and long-term outcomes remains unclear for endoscopy-guided nasojejunal feeding tube (ENFT) placement versus blind nasogastric feeding tube (BNFT) placement on post-COVID-19 ICU patients.

Study Design: A retrospective cohort study comparing BNFT and ENFT placement in ICU patients post-COVID-19 infection.

Objective: To evaluate the impact of BNFT versus ENFT placement methods on complications in post-COVID-19 ICU patients requiring enteral feeding.

Participants: A total of 310 ICU patients were retrospectively analyzed after applying inclusion and exclusion criteria, comprising 99 patients in the ENFT group and 211 patients in the BNFT group.

Setting: The study was conducted in the intensive care units of a tertiary care hospital from September 2023 to November 2023.

Outcome Measures: Primary outcomes included baseline clinical characteristics and symptoms prior to COVID-19 infection. Secondary outcomes assessed post-COVID-19 complications over short (up to 2 weeks), medium (2–4 weeks), and long-term (beyond 4 weeks) periods. These complications included shortness of breath, cognitive dysfunction, muscle and joint pain, sleep disturbances, and gastrointestinal symptoms, measured by GSRS and SAQ scores.

Results: Baseline characteristics were similar between both groups ($p > 0.05$), indicating well-matched cohorts. Post-COVID-19, the ENFT group exhibited significantly lower rates of shortness of breath, cognitive dysfunction, muscle and joint pain, sleep disturbances, and mental health challenges, especially for long-term feeding tube usage ($p < 0.05$). GSRS scores were lower and SAQ scores were higher in the ENFT group, indicating better gastrointestinal and cardiovascular outcomes.

Conclusion: ENFT placement is associated with fewer post-COVID-19 complications compared to BNFT, particularly for patients requiring long-term feeding tube usage in the ICU.

Keywords: nasojejunal tube placement, prone ventilation, post-COVID-19 ICU patients, safety, enteral feeding

Introduction

Early enteral nutrition plays a very important role in the outcome and prognosis of critically ill patients.[1,2] It is associated with a reduction in the incidence of overall adverse events,[3] and mortality rates.[4] Early enteral nutrition in the ICU is provided through gastric feeding via a nasogastric tube as soon as possible for patients unable to eat orally.[5] For those intolerant to this method, nasojejunal feeding through the post-pyloric route ensures nutrition while reducing reflux and aspiration.[6,7] This approach is recommended for ICU patients with COVID-19,[8] who need long-term nutrition support.[9]

The insertion of a feeding tube in ICU patients is a complex procedure that poses several challenges, including safety, procedure accuracy, and operational efficiency.[10] The inability to observe the path of the tube during blind insertion, thereby poses challenges in accurate insertion and leads to adverse events. The lack of direct visual control can lead to disinsertion of the feeding tube into the lungs or stomach.[11] Furthermore, the procedure's time-sensitive nature requires a swift and accurate insertion of the feeding tube to ensure the patient receives the necessary nutritional support promptly.

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Pain and discomfort are common side effects of tube insertion, depending on the location and insertion method.[12] The insertion of a tube can cause dislodgement,[13] gastrointestinal bleeding,[14] pain and discomfort,[15] aspiration pneumonia,[16] infection,[16] ventilator-associated events (VAP),[17] nutritional outcomes,[18] patient and family satisfaction,[19] gastrointestinal problems nausea[12] and diarrhea.[20]

Given these challenges, we develop a visual-guided feeding tube system by adding a microscope to the tip of the feeding tube.[21] The electro-feeding tube microscope is from Jiangsu Jianzhiyuan Medical Equipment Technology Co., Ltd. (model, VGT-200, GT-300, Yangzhou, China) with slight modifications. The end of the guide wires of the feeding tube is equipped with a tiny snake-shaped metal steer, which can be adjusted to guide the direction of the endoscope, enhancing control and visualization. This steer also aids in tube progression through peristalsis. The endoscope itself is composed of a three-layer structure, including polyether-block-amide for the inner and outer layers, and a middle layer woven with 304 stainless steel wire. This construction contributes to the device's durability and flexibility. At the front end of the device, there is a complementary metal-oxide semiconductor (CMOS) image sensor paired with a lens and a tiny light-emitting diode (LED) lamp. The integration of the CMOS and LED technology ensures high-quality imaging and illumination, allowing for clear and detailed visualization of the GI mucosa.

Despite the established differences between BNFT and ENFT, limited research exists that directly compares their long-term outcomes, particularly in post-COVID-19 ICU patients. While BNFT is more accessible and cost-effective, its increased risk of complications poses significant challenges for patients recovering from severe illnesses like COVID-19. On the other hand, ENFT's precision in tube placement and reduced mucosal trauma may offer crucial advantages in preventing complications, especially during the extended recovery period many post-COVID-19 patients experience. Thus, a clear need exists to investigate whether the benefits of ENFT extend beyond initial tube placement to positively affect long-term patient outcomes.

In post-COVID-19 patients, the potential for prolonged gastrointestinal dysfunction and the high incidence of malnutrition underscore the importance of optimizing enteral feeding methods.[22,23] These patients are at risk of developing chronic complications that affect post-COVID-19 patients[24] and may be influenced by the effectiveness of early nutritional interventions. ENFT may not only improve the immediate placement outcomes but also promote better nutrient absorption and gastrointestinal health over time, potentially mitigating long-term complications. Therefore, examining whether ENFT offers superior outcomes in terms of recovery, nutritional status, and reduced post-COVID-19 symptoms is critical.

The choice between ENFT and BNFT placement carries significant clinical implications, as improper tube placement can lead to severe complications such as aspiration pneumonia, malnutrition, and prolonged hospitalization. Despite the importance of this decision, the comparative effectiveness of these two methods in post-COVID-19 ICU patients has not been sufficiently explored in the literature. This gap in research highlights the need for a more thorough investigation into the safety, efficacy, and outcomes of ENFT versus BNFT in this critical patient population. This study aims to address this gap by evaluating the clinical outcomes of post-COVID-19 ICU patients who received either BNFT or ENFT. Specifically, it assesses the impact of these two feeding tube placement methods on long-term recovery, including nutritional status, gastrointestinal complications, and overall patient health. By focusing on post-COVID-19 patients who require prolonged enteral nutrition, this study seeks to determine whether ENFT offers a clinically significant advantage in reducing the risk of complications and improving long-term outcomes compared to BNFT.

Methods

Study Design and Setting

The study aimed to compare the effectiveness and safety of ENFT versus BNFT placement in post-COVID-19 ICU patients, with a focus on post-procedure complications, including gastrointestinal, cognitive, and mental health issues, in both the short and long term. This retrospective cohort study was conducted in the intensive care units (ICUs) of the Fifth Affiliated Hospital of Wenzhou Medical University and Lishui Municipal Central Hospital in China, both of which are tertiary care institutions. The study aimed to evaluate the impact of two nasogastric feeding tube placement methods—ENFT and BNFT placement—on post-COVID-19 complications in ICU patients. The study analyzed 310 ICU patients

who met the inclusion and exclusion criteria. These patients were divided into two groups based on the feeding tube placement method: ENFT group (99 patients) and BNFT group (211 patients).

The data were collected from ICU admissions between June 2023 and September 2023. Both hospitals are equipped with state-of-the-art ICU facilities and provide critical care services to patients with severe COVID-19-related complications. The ICUs follow standardized protocols for feeding tube placement and management. During the study period, all patients in the ICU requiring enteral feeding were eligible for either ENFT or BNFT placement based on clinical judgment and the availability of endoscopy services.

Ethical Considerations

Since this study was a retrospective cohort study, the research design involved reviewing existing patient data that were collected as part of routine clinical care, with no direct intervention or additional data collection from patients. Therefore, the study was considered exempt from the requirement for formal ethical review and approval by the institutional review board (IRB) or ethics committee. In accordance with standard practices for retrospective studies, ethical approval was waived by the ethics committees of Lishui Municipal Central Hospital (The ethical waiver approval number No. 2023–655). This study complies with the Declaration of Helsinki and adheres to all applicable ethical guidelines for the use of patient data, ensuring patient confidentiality and compliance with principles of privacy and data protection.

Sample Size Calculation

The sample size was calculated to compare the duration of nasojejunal feeding tube usage between the ENFT and BNFT groups among critically ill COVID-19 patients. Based on a pilot review of 200 ICU patients (100 ENFT, 100 BNFT) at our institution, we estimated an odds ratio (OR) of 2.1, reflecting a clinically meaningful reduction in the odds of prolonged feeding tube use (beyond 4 weeks) with ENFT compared to BNFT. Using this OR, a two-sided significance level (α) of 0.05, and a power of 0.80, we determined that a minimum of 238 patients was required for a two-group comparison. Accounting for clinical availability and recruitment feasibility, the sample was distributed as 99 patients in the ENFT group and 211 in the BNFT group, yielding a total sample of 310 patients. For the secondary analysis comparing three feeding tube duration periods (up to 2 weeks, 2–4 weeks, and beyond 4 weeks), we estimated a 10–30% increase in sample size to maintain statistical power, depending on the effect size. The achieved sample size of 310 patients was deemed sufficient to detect significant differences in both the primary (ENFT vs BNFT) and secondary (three-period) comparisons. All calculations were performed using standard sample size estimation methods for logistic regression and chi-square tests.

Inclusion Criteria

Patients were included if they: (1) were admitted to the ICU with a confirmed diagnosis of COVID-19 via reverse transcription-polymerase chain reaction (RT-PCR) testing; (2) required nasoenteric feeding tube placement for nutritional support due to inability to eat orally; (3) were on mechanical ventilation; (4) had feeding tube use duration (weeks) and belong to post-COVID-19 more than 6 months; (5) the data available for before COVID-19 infection based on the parameters listed in Table 1 via phone interviewing.

Exclusion Criteria

Patients were excluded if they: (1) had contraindications to nasoenteric tube placement, such as multiple gastrointestinal surgeries or known strictures increasing the risk of perforation; (2) had incomplete data records or errors in data collection; (3) discontinued the intervention prematurely; (4) exhibited extreme or inconsistent data points affecting result accuracy; or (5) had specific contraindications to enteral feeding, such as severe malabsorption syndromes; and (6) the data unavailable for before COVID-19 infection based on the parameters listed in Table 1 via phone interviewing.

Feeding Tube Insertion Procedures

In the BNFT group, the Corflo nasojejunal tube (10 French, 140 cm; Corpak MedSystems, Inc) was inserted according to the Corpak 10–10-10 protocol. Prior to insertion, patients were administered 10 mg of metoclopramide hydrochloride

Table 1 The Parameters with Refined Cutoff Values and Timeframes for Telephone Interviewing

Parameter	Cutoff Values	Timeframe
Fatigue	≥4 on a 10-point scale	Persisting for ≥3 months
Edema	Observable swelling lasting more than 1 week	More than 1 week
Shortness of breath	≥2 on a 5-point scale (where 5 is severe)	Occurring frequently for ≥2 weeks
Cognitive dysfunction	MoCA score <26 (telephone-based MoCA evaluation)	Persistent cognitive difficulties for ≥3 months
Muscle and joint pain	≥4 on a 10-point pain scale	Lasting for ≥1 month
Sleep disturbances	ISI (Insomnia Severity Index) ≥15	Lasting for ≥1 month
Headaches	Pain Scale ≥4 on a 10-point scale	Headaches occurring ≥2 times per week
Loss of taste or smell	Complete or significant reduction	Lasting for ≥2 weeks
Nausea and vomiting	Affecting more than 25% of daily meals	Lasting for more than 2 weeks
Diarrhea	More than 3 loose stools per day	Lasting for more than 3 days
Constipation	A change in bowel habits	Persisting for more than 2 weeks
Acid reflux	Experiencing reflux more than twice a week	Persistent for ≥1 month
Mental health challenges	PHQ-9 score ≥10 (moderate depression threshold)	Present for ≥2 weeks
Weight loss	Loss of more than 10% of body weight	Within a 6-month period
GSRS (gastrointestinal symptoms rating scale)	Average score ≥3 (on a 7-point scale)	Symptoms present for ≥2 weeks
SAQ (Seattle angina questionnaire)	Score ≤75 on 0–100 scale (lower scores indicate worse condition)	Over the last month

intravenously, 10 minutes before the procedure, to promote gastric motility. The nasojejunal tube was lubricated with paraffin oil to ease insertion. Tube insertion length was estimated using the Nose-Ear-Xiphoid (NEX) method, plus an additional 20–30 cm to ensure proper placement into the jejunum. The patient was positioned semi-horizontally at a 30-degree angle to facilitate insertion. The tube was advanced in 5 cm increments, and 10 mL of normal saline was used to flush the tube after each advancement to maintain patency and reduce risk of tube obstruction. Proper placement was confirmed by an abdominal X-ray, which showed the tube tip located beyond the pylorus and duodenum.

The ENFT group followed a similar initial procedure, but with endoscopic guidance for tube placement. Sedation was achieved through midazolam administration at a dose of 0.05 mg/kg intravenously. The endoscope was introduced through the mouth to visualize the esophagus, stomach, and pylorus. Under real-time visualization, the tube was guided into the jejunum. After removal of the stylet, tube position was verified by abdominal X-ray. If additional confirmation was required, ultrasound was used as a supplementary imaging modality to ensure optimal tube placement.

Symptom Evaluation

Symptoms were assessed longitudinally via telephone interviews conducted before COVID-19 infection and more than six months post-infection to track changes in health, particularly in post-COVID-19 ICU patients comparing nasojejunal feeding tube placement (ENFT vs BNFT). Validated scales with established cutoffs identified persistent symptoms and their progression. Fatigue was measured on a 10-point scale, with a score ≥4 indicating significant fatigue lasting ≥3 months. Visible swelling persisting >1 week was deemed significant to distinguish transient from persistent fluid retention. Cognitive function was evaluated using the Montreal Cognitive Assessment (MoCA), adapted for telephone use, with a score <26 indicating cognitive impairment lasting ≥3 months. Pain intensity was assessed on a 10-point scale, with a score ≥4 indicating significant muscle/joint pain persisting ≥1 month. Gastrointestinal symptoms, including abdominal pain, reflux, and diarrhea, were assessed using the Gastrointestinal Symptom Rating Scale (GSRS, score ≥3 indicating moderate-to-severe symptoms), crucial for evaluating digestive function impacted by feeding tube placement, as post-COVID-19 ICU patients often face persistent gastrointestinal issues due to prolonged critical illness. Mental health was evaluated using the Patient Health Questionnaire-9 (PHQ-9, score ≥10 indicating moderate depression, persisting ≥2 weeks). Specific gastrointestinal criteria included nausea/vomiting affecting >25% of daily meals for >2 weeks and diarrhea with >3 loose stools/day for ≥3 days. The Seattle Angina Questionnaire (SAQ, summary score <75 suggesting significant angina burden) captured cardiovascular recovery, given frequent cardiac complications in COVID-19 survivors. These thresholds (Table 1) support assessment of long-term recovery outcomes, like reduced symptom burden as a marker of improved nutritional and functional status.

Clinical Data Collection and Variables of Post-COVID-19 Patients

Clinical data were extracted from electronic medical records (EMRs) and entered into a standardized database by trained research staff. Key variables included laboratory values: inflammatory markers (eg, C-reactive protein (CRP)) and nutritional parameters (eg, serum albumin levels); ventilator-associated events: documented based on clinical criteria and diagnostic imaging; respiratory distress episodes: identified through clinical assessments and diagnostic imaging findings; pre- and post-COVID-19 data: data on baseline health and post-COVID-19 outcomes were collected through telephone-based interviews conducted from June 2023 to September 2023. Standardized data extraction sheets were used to capture patient demographics (eg, age, sex, comorbidities) and clinical information (eg, date of last confirmed COVID-19 infection).

Data Standardization

To ensure consistency and reliability, all symptom and condition assessments adhered to standardized criteria as outlined in Table 1. Data collection procedures and instruments, including the symptom scales and interview methods, were predefined to ensure reproducibility across participants and time points.

Primary Outcome

The primary outcomes of this study focus on the baseline symptom severity and frequency recorded prior to COVID-19 infection. These will include symptoms such as fatigue, cognitive dysfunction, muscle and joint pain, sleep disturbances, and others. Symptoms will be assessed using standardized scales, including the 10-point pain scale for muscle and joint pain, the MoCA for cognitive function, and the GSRS for gastrointestinal symptoms. Telephone interviews will be conducted by trained personnel, following a predefined set of questions to ensure consistent data collection. Symptoms will be measured based on prevalence, intensity, and duration, establishing a baseline for each patient's health prior to infection.

Secondary Outcome

The secondary outcomes focused on changes in symptom severity and frequency more than six months post-COVID-19 infection. Symptoms such as shortness of breath, cognitive dysfunction, muscle and joint pain, sleep disturbances, and mental health challenges will be tracked. Gastrointestinal symptoms will be assessed using the GSRS, and cardiovascular symptoms will be captured with the SAQ. The same scales used for baseline assessments will be utilized to ensure comparability. These secondary outcomes will help assess whether new symptoms have emerged or if pre-existing symptoms have worsened after the COVID-19 infection.

Outcome Evaluation

The evaluation of secondary outcomes will compare post-COVID-19 data with baseline measurements to determine the progression or emergence of symptoms. Symptoms will be categorized based on severity and duration, with specific attention paid to any chronic conditions or changes that may have developed. For instance, muscle and joint pain will be considered significant if the intensity is ≥ 4 on the 10-point scale, while cognitive dysfunction will be assessed using the MoCA score of <26. Mental health symptoms will be evaluated using the PHQ-9, and sleep disturbances will be noted if they persist beyond a certain threshold.

Long-Term Impact

The secondary outcomes will also assess the long-term impact of COVID-19, particularly how symptoms affect patients' quality of life. Persistent symptoms, such as chronic fatigue or shortness of breath, will be evaluated for their duration and impact on daily living. Additionally, this section will focus on patient-reported outcomes, such as changes in mental health and physical health as a result of the pandemic. By comparing the progression or persistence of symptoms from baseline to post-COVID, this study aims to deepen understanding of post-COVID-19 syndrome and its long-term effects on patient health.

Data Quality Control

To ensure data reliability, double data entry was performed by two independent researchers. Any discrepancies were resolved by referring back to the original medical records. Regular meetings were held to address data collection issues and maintain consistency across both study sites.

Confounding Factors

Confounding factor analysis is crucial to accurately assess the association between COVID-19 infection and long-term health outcomes. In the context of Tables 1 and 2, several baseline characteristics and symptom variables could act as

Table 2 Basic Clinical Characters Between Two Groups

Parameter	BNFT (n = 211)	ENFT (n = 99)	*t* or χ^2	*p*
Age (years)	75.75 ± 8.77	65.07 ± 8.59	0.432	0.401
Female (%)	89 (42.18%)	45 (45.45%)	0.294	0.587
ICU admission				
Severe Hypoxia (%)	149 (70.62%)	77 (77.78%)	1.750	0.186
ARDS (%)	21 (9.95%)	10 (10.10%)	0.002	0.968
Multi-organ Failure (%)	33 (15.64%)	14 (14.14%)	0.118	0.732
Others				
NIHSS (points)	6.55 ± 2.03	6.92 ± 1.17	2.78	0.051
Blood Pressure (mmHg)	151.8 ± 13.2	148.4 ± 13.9	0.22	0.901
Heart Rate (beats per minute)	90.39 ± 6.79	91.32 ± 6.69	0.85	0.547
Respiratory Rate (breaths/min)	18.28 ± 3.03	16.20 ± 2.48	2.83	0.08
Glasgow Coma Scale (GCS)	14.66 ± 0.92	13.94 ± 1.07	0.88	0.552
Comorbidities				
Hypertension (%)	121 (57.35%)	57 (57.58%)	0.001	0.970
Diabetes Mellitus (%)	83 (39.34%)	43 (43.43%)	0.469	0.493
Dyslipidemia (%)	78 (36.97%)	41 (41.41%)	0.564	0.453
Previous Stroke or TIA	25 (11.85%)	15 (15.15%)	0.654	0.419
Atrial Fibrillation or Arrhythmias	54 (25.59%)	23 (23.23%)	0.201	0.654
Chronic Kidney Disease (%)	12 (5.69%)	5 (5.05%)	0.053	0.818
Obesity (%)	83 (39.34%)	38 (38.38%)	0.026	0.873
Thrombolysis (%)	78 (36.97%)	33 (33.33%)	0.387	0.534
Mechanical Thrombectomy (%)	38 (18.01%)	22 (22.22%)	0.766	0.381
Modified Rankin Scale (mRS)	1.87 ± 0.41	1.50 ± 0.48	0.83	0.107
Barthel Index (points)	103.4 ± 13.4	108.4 ± 16.3	0.48	0.693
Blood Glucose Levels (mg/dL)	145.4 ± 29.4	150.3 ± 28.7	0.74	0.578
Respiratory Distress Parameters				
SpO_2 (%)	83.4 ± 3.5	80.9 ± 3.8	2.17	0.136
FiO_2 (%)	75.8 ± 7.4	70.4 ± 10.7	2.03	0.195
PaO_2/FiO_2 Ratio	128.3 ± 33.7	112.4 ± 31.6	1.47	0.241
Systemic Inflammatory Response Parameters				
CRP (mg/L)	13.10 ± 5.43	12.28 ± 5.98	2.68	0.060
TNF-α (pg/mL)	42.88 ± 4.78	34.71 ± 6.59	0.26	0.511
IL-6 (pg/mL)	157 ± 21	155 ± 24	0.56	0.337
Ferritin (ng/mL)	794 ± 114	791 ± 154	2.29	0.072
Procalcitonin (ng/mL)	0.34 ± 0.15	0.43 ± 0.24	2.44	0.096
D-dimer (μg/mL)	3.11 ± 0.35	3.21 ± 0.60	0.27	0.621
Lymphocyte Count (10^3/μL)	1.74 ± 0.21	1.78 ± 0.18	0.42	0.684
Erythrocyte Sedimentation Rate (mm/h)	22.72 ± 4.69	26.79 ± 6.76	0.23	0.802

(*Continued*)

Table 2 (Continued).

Parameter	BNFT (n = 211)	ENFT (n = 99)	*t* or χ^2	*p*
Nutritional Levels				
Serum Prealbumin (mg/dL)	10.30 ± 1.26	9.26 ± 1.35	2.47	0.076
Serum Albumin (g/dL)	3.21 ± 1.36	3.25 ± 1.26	0.17	0.938
Serum Total Protein (g/dL)	5.79 ± 1.28	5.70 ± 1.26	1.53	0.319
Feeding tube use				
Up to 2 weeks	81 (38.39%)	31 (31.31%)	1.46	0.227
2 to 4 weeks	64 (30.33%)	35 (35.35%)	0.78	0.377
Beyond 4 weeks	62 (29.38%)	33 (33.33%)	0.49	0.482
Post time since discharge from ICU (months)	17.46 ± 6.91	18.24 ± 5.84	0.53	0.443

Note: There are significant differences if $p < 0.05$.
Abbreviations: ENFT, endoscopy-guided nasojejunal feeding tube; BNFT, blind bedside nasojejunal feeding tube; ARDS, Acute Respiratory Distress Syndrome; NIHSS, NIH stroke score; GCS, Glasgow Coma Scale; SpO_2, Oxygen Saturation; TNF-α, Tumor Necrosis; Factor-α; CRP, C-reactive protein and IL-6: Interleukin-6. Short-term use: up to 2 weeks; Medium-term use:2 to 4 weeks and long-term use beyond 4 weeks.

confounders. For example, age, sex, and comorbidities like hypertension, diabetes mellitus, and chronic kidney disease could influence both the likelihood of severe COVID-19 outcomes and the persistence of symptoms such as fatigue, cognitive dysfunction, and muscle pain. To address confounding, multivariable regression models can be used to control for these variables, ensuring that the associations between post-COVID symptoms and long-term outcomes are not falsely attributed to underlying baseline factors. Additionally, propensity score matching or stratification by key confounders (eg, ICU admission or comorbidities) could help isolate the effect of specific variables, such as respiratory or gastrointestinal symptoms, on recovery patterns.

In addition, systemic inflammatory markers (eg, CRP, IL-6, ferritin) and respiratory parameters (eg, PaO2/FiO2 ratio, SpO2) could act as confounders in examining the relationship between COVID-19 severity and long-term health outcomes. Patients with higher baseline inflammation or respiratory distress are more likely to experience prolonged recovery and persistent symptoms. To control for these confounders, hierarchical models or interaction terms could be incorporated to adjust for the severity of the acute infection phase. Confounding analysis should also account for interventions like mechanical thrombectomy, thrombolysis, and the use of anticoagulant therapies, which may affect post-ICU recovery independently of COVID-19 infection severity. By carefully adjusting for these confounding factors, the analysis can more accurately pinpoint the true impact of COVID-19 on long-term symptoms and patient health outcomes.

Sensitivity Analysis

The sensitivity analysis for the parameters outlined in Tables 1 and 2 involves evaluating how variations in each parameter affect the outcomes of telephone interviews before and after more than 6 months of COVID-19 infection. For the post-COVID-19 symptom parameters (Table 1), sensitivity analysis can be conducted using univariate or multivariate regression models to assess how each symptom, such as fatigue, shortness of breath, cognitive dysfunction, and muscle pain, influences patient-reported outcomes. Interaction terms can also be included to explore whether combinations of symptoms exacerbate or mitigate overall patient health status. Techniques like Monte Carlo simulations or bootstrapping could be applied to understand the variability in symptom reporting and its potential impact on quality of life or the progression of long COVID. Additionally, subgroup analyses may be performed based on demographic or clinical characteristics (eg, age, sex, or comorbidities) to identify differential sensitivity of symptoms in distinct patient populations.

For the baseline characteristics (Table 2), sensitivity analysis would focus on key clinical variables such as age, ICU admission, blood pressure, heart rate, and systemic inflammatory response parameters (eg, CRP, IL-6, D-dimer) to examine their influence on long-term outcomes. Logistic regression or Cox proportional hazards models can be employed to assess how variations in these baseline characteristics are associated with post-discharge recovery trajectories,

including respiratory function, nutritional status, and functional outcomes (eg, mRS and Barthel Index). To account for correlations between variables, a sensitivity analysis could incorporate generalized estimating equations (GEE) or mixed-effects models, especially in cases where patients experienced multi-organ failure or required mechanical interventions like thrombectomy or thrombolysis. This approach allows for a more comprehensive understanding of how baseline factors contribute to recovery patterns post-COVID-19.

Statistical Analysis

Propensity score matching (PSM) was conducted to ensure baseline comparability and minimize selection bias between the ENFT group (n=99) and the BNFT group (n=211). Using R (version 4.2.3) with the MatchIt package, propensity scores were estimated via logistic regression, with ENFT versus BNFT as the outcome. Covariates included age, sex, severe hypoxia, ARDS, multi-organ failure, NIHSS, Glasgow Coma Scale (GCS), Modified Rankin Scale (mRS), Barthel Index, hypertension, diabetes mellitus, obesity, PaO2/FiO2 ratio, SpO2, C-reactive protein (CRP), ferritin, serum prealbumin, serum albumin, thrombolysis, and mechanical thrombectomy. Continuous variables (eg, age, NIHSS) were modeled as linear terms, and categorical variables (eg, sex, hypertension) were binary. One-to-one nearest-neighbor matching without replacement was performed with a caliper of 0.2 to ensure close matches. Balance was confirmed post-matching using standardized mean differences (<0.1) and statistical tests (t-tests for continuous variables, χ^2-tests for categorical variables), with $p > 0.05$ for all covariates indicating no significant differences.

Statistical analyses were performed using SPSS (version 26.0, IBM Corp., Armonk, NY, USA) and R (version 4.2.3, R Foundation for Statistical Computing, Vienna, Austria). Continuous variables were reported as mean ± standard deviation (SD) for normally distributed data or median (interquartile range) for non-normally distributed data, with normality assessed via the Shapiro–Wilk test. Group comparisons (ENFT vs BNFT) used independent Student's t-tests for normally distributed continuous variables or Mann–Whitney *U*-tests for non-normally distributed data. Categorical variables were expressed as frequencies and percentages and compared using χ^2-tests or Fisher's exact tests when expected cell counts were <5.

For secondary analyses comparing feeding tube duration periods (up to 2 weeks, 2–4 weeks, beyond 4 weeks), categorical outcomes were analyzed using χ^2-tests, and continuous outcomes were evaluated with one-way ANOVA (for normally distributed data) or Kruskal–Wallis tests (for non-normally distributed data). Missing data were minimal (<5%) and handled via listwise deletion. All tests were two-sided, with $p < 0.05$ considered statistically significant. No adjustments for multiple comparisons were applied, as analyses were hypothesis-driven and focused on predefined outcomes.

Results

Baseline Characteristics

The flowchart (Figure 1) illustrates the process of patient inclusion in this retrospective study of ICU patients requiring enteral feeding before and after COVID-19 infection. After applying the inclusion and exclusion criteria and excluding cases with extreme data, the final analysis included 99 patients in the endoscopy-guided nasogastric feeding tube (ENFT) group and 211 patients in the blind nasogastric feeding tube (BNFT) group.

The results presented in Table 2 compare various clinical parameters between the BNFT and ENFT groups. Most comparisons between the groups did not show statistically significant differences ($p > 0.05$). For example, parameters such as age, gender distribution, severe hypoxia, ARDS, and multi-organ failure were comparable between the two groups, with p-values of 0.401, 0.587, 0.186, and 0.968, respectively. Similarly, comorbidities like hypertension, diabetes mellitus, dyslipidemia, and atrial fibrillation did not differ significantly between the groups ($p > 0.4$).

Notably, NIH stroke score (NIHSS), blood pressure, and Glasgow Coma Scale (GCS) scores also showed no significant differences. These results suggest that the baseline clinical characteristics were generally balanced between the two groups, indicating that differences in outcomes are unlikely to be influenced by these baseline factors. Additionally, parameters such as oxygenation (SpO_2, FiO_2), inflammatory markers (CRP, TNF-α, IL-6), and nutritional levels (serum albumin, total protein) did not show significant differences, with p-values exceeding 0.05. This suggests

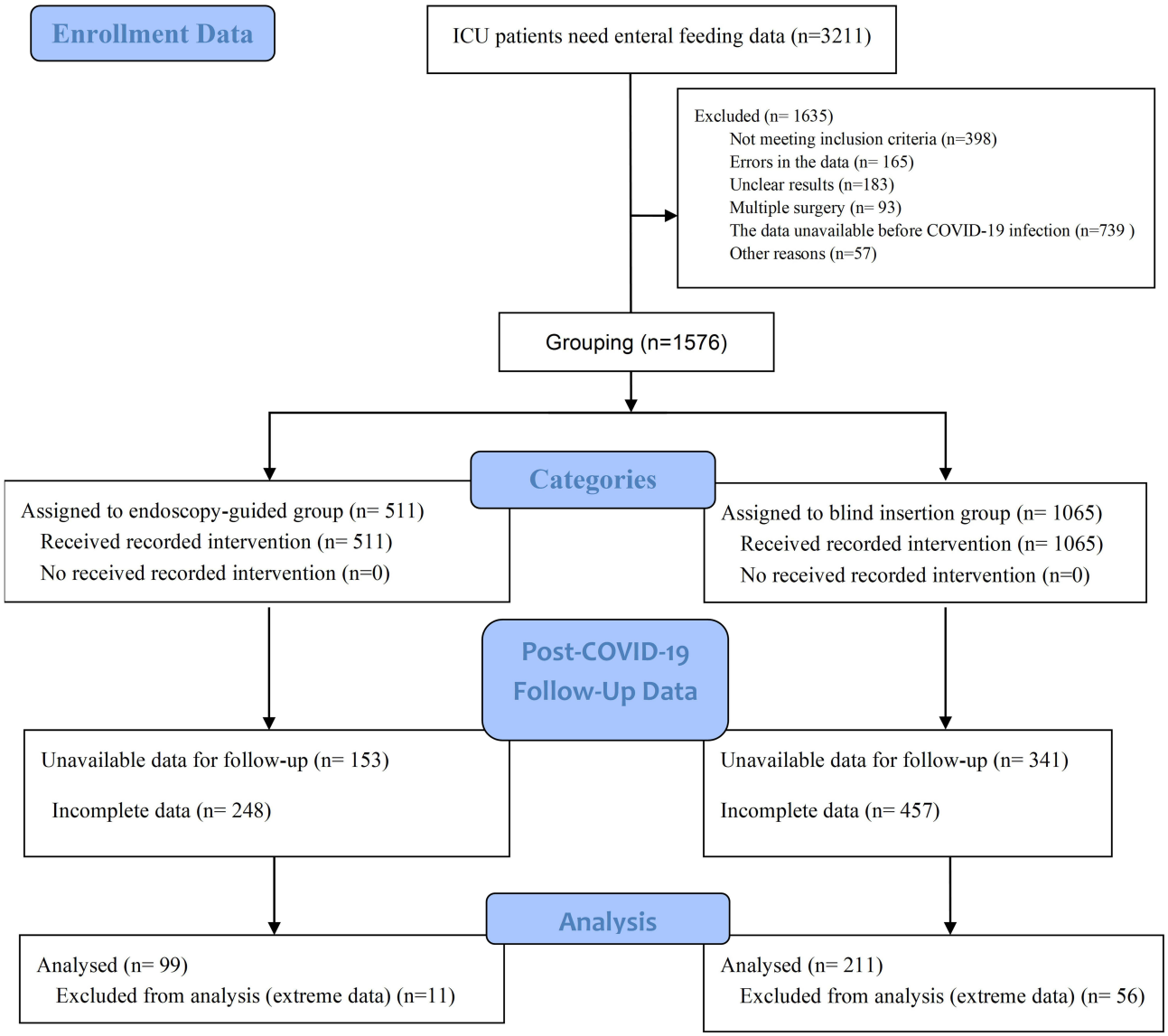

Figure 1 Flow diagram of a retrospective study comparing endoscopy-guided tube insertion and blind bed-side tube insertion in ICU patients before COVID-19 infection and more than 6-month post-COVID-19. The diagram illustrates the grouping of participants based on pre-existing data, detailing the number of participants at each stage of the study. Reasons for exclusion, such as not meeting inclusion criteria and extreme data points, as well as the lack of follow-up records and discontinuations, are provided.

that most clinical and laboratory characteristics were similar across the groups, and the choice of feeding tube placement method did not significantly impact these parameters during the post-COVID-19 follow-up.

After propensity score matching, 90 matched pairs of ENFT and BNFT patients (n=90 each) were obtained, with 9 ENFT and 121 BNFT patients excluded due to insufficient overlap in propensity scores. Post-matching, all baseline characteristics from Table 2 were well-balanced between the ENFT and BNFT groups, with no significant differences (all $p > 0.05$, Table 3). For example, age (ENFT: 70.2 ± 8.6 years vs BNFT: 71.1 ± 8.8 years, p=0.614), sex (ENFT: 43.3% female vs BNFT: 44.4% female, p=0.876), NIHSS (ENFT: 6.7 ± 1.9 vs BNFT: 6.6 ± 2.0, p=0.789), and PaO2/FiO2 ratio (ENFT: 120.5 ± 32.1 vs BNFT: 118.9 ± 33.0, p=0.742) showed comparable distributions. Similarly, comorbidities (eg, hypertension: ENFT: 56.7% vs BNFT: 57.8%, p=0.871) and inflammatory markers (eg, CRP: ENFT: 12.8 ± 5.5 mg/L vs BNFT: 12.5 ± 5.7 mg/L, p=0.698) were balanced. Standardized mean differences for all covariates were <0.1, confirming successful matching. The updated Table 2, reflecting the matched cohort, is included in the revised manuscript, and subsequent analyses of outcomes were conducted using this matched sample to ensure that differences in outcomes are attributable to the feeding tube placement method rather than baseline characteristics.

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Table 3 Propensity Score Matching Results Between Two Groups

Parameter	BNFT (n=90)	ENFT (n=90)	t or χ^2	p
Age (years)	71.1 ± 8.8	70.2 ± 8.6	0.51	0.614
Female (%)	40 (44.4%)	39 (43.3%)	0.03	0.876
Severe Hypoxia (%)	65 (72.2%)	66 (73.3%)	0.03	0.862
ARDS (%)	9 (10.0%)	9 (10.0%)	0	1
Multi-organ Failure (%)	14 (15.6%)	13 (14.4%)	0.05	0.836
NIHSS (points)	6.6 ± 2.0	6.7 ± 1.9	0.27	0.789
Blood Pressure (mmHg)	150.2 ± 13.5	149.8 ± 13.7	0.19	0.85
Heart Rate (beats per minute)	90.8 ± 6.7	91.0 ± 6.8	0.17	0.866
Respiratory Rate (breaths/min)	17.5 ± 2.9	17.3 ± 2.8	0.34	0.734
Glasgow Coma Scale (GCS)	14.5 ± 0.9	14.4 ± 1.0	0.45	0.652
Hypertension (%)	52 (57.8%)	51 (56.7%)	0.03	0.871
Diabetes Mellitus (%)	36 (40.0%)	37 (41.1%)	0.03	0.874
Dyslipidemia (%)	35 (38.9%)	34 (37.8%)	0.03	0.876
Previous Stroke or TIA	12 (13.3%)	12 (13.3%)	0	1
Atrial Fibrillation or Arrhythmias	22 (24.4%)	21 (23.3%)	0.03	0.863
Chronic Kidney Disease (%)	5 (5.6%)	5 (5.6%)	0	1
Obesity (%)	35 (38.9%)	34 (37.8%)	0.03	0.876
Thrombolysis (%)	33 (36.7%)	32 (35.6%)	0.03	0.874
Mechanical Thrombectomy (%)	18 (20.0%)	18 (20.0%)	0	1
Modified Rankin Scale (mRS)	1.7 ± 0.4	1.6 ± 0.4	0.89	0.375
Barthel Index (points)	105.2 ± 14.1	104.8 ± 14.3	0.18	0.857
Blood Glucose Levels (mg/dL)	147.3 ± 28.9	146.8 ± 29.1	0.11	0.912
SpO2 (%)	82.1 ± 3.6	82.3 ± 3.5	0.31	0.756
FiO2 (%)	73.2 ± 8.1	72.9 ± 8.3	0.22	0.827
PaO2/FiO2 Ratio	118.9 ± 33.0	120.5 ± 32.1	0.33	0.742
CRP (mg/L)	12.5 ± 5.7	12.8 ± 5.5	0.39	0.698
TNF-α (pg/mL)	38.9 ± 5.2	39.1 ± 5.1	0.23	0.819
IL-6 (pg/mL)	156 ± 22	155 ± 23	0.25	0.803
Ferritin (ng/mL)	792 ± 120	790 ± 118	0.11	0.915
Procalcitonin (ng/mL)	0.38 ± 0.18	0.39 ± 0.17	0.33	0.742
D-dimer (μg/mL)	3.15 ± 0.40	3.14 ± 0.41	0.15	0.88
Lymphocyte Count (10^3/μL)	1.76 ± 0.20	1.75 ± 0.21	0.27	0.789
Erythrocyte Sedimentation Rate (mm/h)	24.1 ± 5.2	24.3 ± 5.1	0.22	0.827
Serum Prealbumin (mg/dL)	9.8 ± 1.3	9.9 ± 1.2	0.41	0.682
Serum Albumin (g/dL)	3.23 ± 1.30	3.24 ± 1.29	0.05	0.961
Serum Total Protein (g/dL)	5.75 ± 1.27	5.76 ± 1.26	0.05	0.961
Up to 2 weeks	33 (36.7%)	32 (35.6%)	0.03	0.874
2 to 4 weeks	28 (31.1%)	29 (32.2%)	0.03	0.874
Beyond 4 weeks	29 (32.2%)	29 (32.2%)	0	1
Post time since discharge from ICU (months)	17.8 ± 6.5	17.7 ± 6.6	0.09	0.926

Observation of Digestive Tract

With the help of ENFT insertion, different parts of the digestive tract were clearly observed, including nostril entrance (Figure 2A), turbinates (Figure 2B), oesophagus (Figure 2C), open cardia (Figure 2D), closed cardia (Figure 2E), greater curvature mucosa with ichthyosis-like villi (Figure 2F), gastric antrum mucosa with reticular-structured villi (Figure 2G), pylorus opening (Figure 2H), pylorus gate (Figure 2I), duodenal villi from different angles (Figure 2J–L). The final results were confirmed via X-ray confirmation (Figure 2M–O). The results suggest that the digestive tract can be observed via endoscopy.

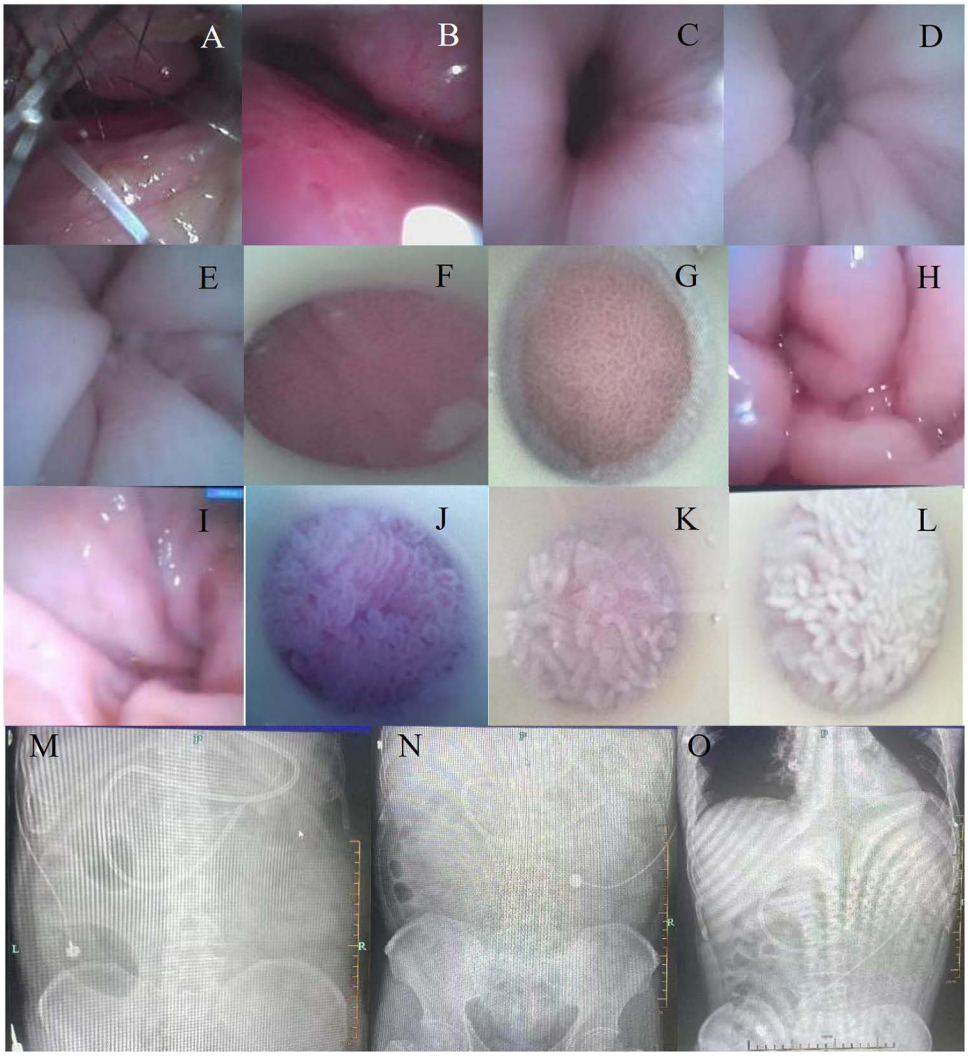

Figure 2 Endoscopic observations of different parts of digestive tract. The image presents endoscopic observations of various parts of the digestive tract, starting with the nasal vestibule (**A**), which is lined with thick nasal hair to filter dust. The nasal passage (**B**) is anatomically complex, with mucous membrane-covered nasal conchae that regulate airflow. The esophagus (**C**) appears smooth and light red, transitioning to the cardiac orifice (**D**), where the relaxed mucosa resembles a rosebud. The pyloric orifice (**H** and **I**) demonstrates annular folds, leading to the narrowest part of the digestive tract. Additionally, intestinal villi (**J–L**) differ in shape across the duodenum, jejunum, and ileum, which are essential for nutrient absorption. Lastly, X-ray confirmation (**M–O**) shows successful nasojejunal tube insertion into the digestive tract.

Primary Outcome

The primary outcomes before COVID-19 infection showed that there were no statistically significant differences between the BNFT and ENFT groups for most symptoms at all three timeframes (short, middle, and long-term) (Table 4). In the short term, symptoms such as fatigue, edema, and shortness of breath were observed at similar rates between the groups

Table 4 Before COVID-19 Infection

Parameter	BNFT	ENFT	*t* or χ^2	*p*
Short term (cases)	81	31		
Fatigue	5 (6.17%)	2 (6.45%)	0.003	0.957
Edema	4 (4.94%)	1 (3.23%)	0.154	0.695
Shortness of Breath	3 (3.70%)	1 (3.23%)	0.015	0.903
Cognitive Dysfunction	6 (7.41%)	2 (6.45%)	0.031	0.861

(*Continued*)

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Table 4 (Continued).

Parameter	BNFT	ENFT	t or χ^2	p
Muscle and Joint Pain	7 (8.64%)	3 (9.68%)	0.030	0.863
Sleep Disturbances	4 (4.94%)	2 (6.45%)	0.101	0.750
Headaches	2 (2.47%)	1 (3.23%)	0.049	0.824
Loss of Taste or Smell	5 (6.17%)	2 (6.45%)	0.003	0.957
Nausea and Vomiting	3 (3.70%)	2 (6.45%)	0.397	0.529
Diarrhea	3 (3.70%)	1 (3.23%)	0.015	0.903
Constipation	4 (4.94%)	1 (3.23%)	0.154	0.695
Acid Reflux	5 (6.17%)	2 (6.45%)	0.003	0.957
Mental Health Challenges	3 (3.70%)	2 (6.45%)	0.397	0.529
Weight Loss	6 (7.41%)	3 (9.68%)	0.156	0.693
GSRS	1.72 ± 0.36	1.53 ± 0.45	0.95	0.325
SAQ	74.6 ± 20.3	68.0 ± 18.5	1.05	0.238
Middle term (cases)	64	35		
Fatigue	8 (12.50%)	4 (11.43%)	0.024	0.876
Edema	6 (9.38%)	3 (8.57%)	0.018	0.894
Shortness of Breath	5 (7.81%)	2 (5.71%)	0.152	0.697
Cognitive Dysfunction	7 (10.94%)	3 (8.57%)	0.139	0.709
Muscle and Joint Pain	6 (9.38%)	4 (11.43%)	0.105	0.746
Sleep Disturbances	5 (7.81%)	3 (8.57%)	0.018	0.895
Headaches	4 (6.25%)	2 (5.71%)	0.011	0.915
Loss of Taste or Smell	6 (9.38%)	3 (8.57%)	0.018	0.894
Nausea and Vomiting	4 (6.25%)	3 (8.57%)	0.186	0.667
Diarrhea	5 (7.81%)	2 (5.71%)	0.152	0.697
Constipation	5 (7.81%)	3 (8.57%)	0.018	0.895
Acid Reflux	7 (10.94%)	4 (11.43%)	0.006	0.941
Mental Health Challenges	5 (7.81%)	3 (8.57%)	0.018	0.895
Weight Loss	8 (12.50%)	4 (11.43%)	0.024	0.876
GSRS	2.32 ± 0.37	2.38 ± 0.49	1.22	0.251
SAQ	69.8 ± 28.8	64.4 ± 26.2	1.41	0.328
Long term (cases)	62	33		
Fatigue	12 (19.35%)	6 (18.18%)	0.019	0.890
Edema	10 (16.13%)	4 (12.12%)	0.275	0.600
Shortness of Breath	8 (12.90%)	3 (9.09%)	0.306	0.580
Cognitive Dysfunction	11 (17.74%)	5 (15.15%)	0.103	0.748
Muscle and Joint Pain	9 (14.52%)	5 (15.15%)	0.007	0.934
Sleep Disturbances	10 (16.13%)	5 (15.15%)	0.015	0.901
Headaches	8 (12.90%)	4 (12.12%)	0.012	0.913
Loss of Taste or Smell	9 (14.52%)	4 (12.12%)	0.105	0.746
Nausea and Vomiting	8 (12.90%)	3 (9.09%)	0.306	0.580
Diarrhea	8 (12.90%)	3 (9.09%)	0.306	0.580
Constipation	9 (14.52%)	4 (12.12%)	0.105	0.746
Acid Reflux	11 (17.74%)	6 (18.18%)	0.003	0.958
Mental Health Challenges	9 (14.52%)	4 (12.12%)	0.105	0.746
Weight Loss	12 (19.35%)	5 (15.15%)	0.259	0.611
GSRS	2.91 ± 0.46	2.86 ± 0.38	0.68	0.425
SAQ	65.60 ±26.94	66.18 ± 21.23	0.85	0.314

Abbreviations: GSRS, Gastrointestinal Symptoms Rating Scale; SAQ, Seattle Angina Questionnaire; Feeding tube use cases: Short term, up to 2 weeks; Middle term, 2 to 4 weeks and Long term, beyond 4 weeks.

($p > 0.05$), indicating no significant differences. For instance, fatigue was reported in 6.17% of the BNFT group and 6.45% of the ENFT group ($p = 0.957$). Similarly, other symptoms such as cognitive dysfunction and mental health challenges showed no notable variance between groups, with p-values of 0.861 and 0.529, respectively. The GSRS and SAQ scores also did not differ significantly between the two groups, with p-values of 0.325 and 0.238, respectively. These findings suggest that the baseline health status before COVID-19 was similar between the groups.

In the middle and long-term periods, the trend continued, with no significant differences observed between the BNFT and ENFT groups for symptoms such as muscle and joint pain, headaches, and nausea and vomiting. For example, in the middle-term period, 12.50% of BNFT patients and 11.43% of ENFT patients reported fatigue ($p = 0.876$), and in the long-term period, 19.35% of BNFT patients and 18.18% of ENFT patients reported fatigue ($p = 0.890$). Both the GSRS and SAQ scores showed no significant differences, with p-values consistently greater than 0.05. Overall, these findings suggest that the pre-COVID-19 health status was comparable between the groups, minimizing any impact of baseline characteristics on the post-COVID-19 analysis.

Secondary Outcome

The secondary outcomes assessed more than six months after COVID-19 infection revealed several statistically significant differences between the BNFT and ENFT groups (Table 5). In the short-term period (up to two weeks), significant differences were observed for symptoms such as shortness of breath ($p = 0.009$), cognitive dysfunction ($p = 0.011$), muscle and joint pain ($p = 0.023$), sleep disturbances ($p = 0.021$), and headaches ($p = 0.013$), all of which were

Table 5 Post-COVID-19 Infection More Than 6 months

Parameter	BNFT	ENFT	t or χ^2	p
Short term (cases)	81	31		
Fatigue	19 (23.46%)	7 (22.58%)	0.010	0.922
Edema	19 (23.46%)	6 (19.35%)	0.218	0.641
Shortness of Breath	24 (29.63%)	2 (6.45%)	6.757	0.009
Cognitive Dysfunction	27 (33.33%)	3 (9.68%)	6.397	0.011
Muscle and Joint Pain	28 (34.57%)	4 (12.90%)	5.156	0.023
Sleep Disturbances	25 (30.86%)	3 (9.68%)	5.367	0.021
Headaches	23 (28.40%)	2 (6.45%)	6.226	0.013
Loss of Taste or Smell	16 (19.75%)	3 (9.68%)	1.616	0.204
Nausea and Vomiting	14 (17.28%)	3 (9.68%)	1.008	0.315
Diarrhea	16 (19.75%)	2 (6.45%)	2.941	0.086
Constipation	9 (11.11%)	2 (6.45%)	0.550	0.458
Acid Reflux	6 (7.41%)	3 (9.68%)	0.156	0.693
Mental Health Challenges	11 (13.58%)	3 (9.68%)	0.312	0.576
Weight Loss	13 (16.05%)	4 (12.90%)	0.172	0.678
GSRS	2.72 ± 0.36	2.53 ± 0.45	1.65	0.152
SAQ	64.61 ± 21.33	61.04 ± 24.57	1.45	0.168
Middle term (cases)	64	35		
Fatigue	26 (40.62%)	12 (34.29%)	0.384	0.535
Edema	24 (37.50%)	11 (31.43%)	0.365	0.546
Shortness of Breath	27 (42.19%)	4 (11.43%)	9.953	0.002
Cognitive Dysfunction	29 (45.31%)	5 (14.29%)	9.660	0.002
Muscle and Joint Pain	28 (43.75%)	6 (17.14%)	7.104	0.008
Sleep Disturbances	37 (57.81%)	5 (14.29%)	17.550	0.000
Headaches	26 (40.62%)	4 (11.43%)	9.132	0.003
Loss of Taste or Smell	21 (32.81%)	5 (14.29%)	4.010	0.045
Nausea and Vomiting	16 (25.00%)	5 (14.29%)	1.554	0.213
Diarrhea	27 (42.19%)	4 (11.43%)	9.953	0.002
Constipation	17 (26.56%)	11 (31.43%)	0.264	0.607

(*Continued*)

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Table 5 (Continued).

Parameter	BNFT	ENFT	*t* or χ^2	*p*
Acid Reflux	19 (29.69%)	6 (17.14%)	1.886	0.170
Mental Health Challenges	37 (57.81%)	5 (14.29%)	17.550	0.000
Weight Loss	21 (32.81%)	6 (17.14%)	2.801	0.094
GSRS	3.92 ± 0.87	3.68 ± 0.98	2.15	0.037
SAQ	50.43 ± 16.26	59.85 ± 8.80	2.64	0.024
Long term (cases)	62	33		
Fatigue	32 (51.61%)	11 (33.33%)	2.905	0.088
Edema	38 (61.29%)	12 (36.36%)	5.368	0.021
Shortness of Breath	30 (48.39%)	5 (15.15%)	10.224	0.001
Cognitive Dysfunction	33 (53.23%)	7 (21.21%)	9.055	0.003
Muscle and Joint Pain	29 (46.77%)	7 (21.21%)	5.980	0.014
Sleep Disturbances	32 (51.61%)	7 (21.21%)	8.225	0.004
Headaches	35 (56.45%)	6 (18.18%)	12.858	0.000
Loss of Taste or Smell	41 (66.13%)	10 (30.30%)	11.117	0.001
Nausea and Vomiting	20 (32.26%)	5 (15.15%)	3.250	0.071
Diarrhea	26 (41.94%)	5 (15.15%)	7.028	0.008
Constipation	18 (29.03%)	16 (48.48%)	3.546	0.060
Acid Reflux	33 (53.23%)	8 (24.24%)	7.375	0.007
Mental Health Challenges	41 (66.13%)	6 (18.18%)	19.807	0.000
Weight Loss	24 (38.71%)	7 (21.21%)	2.999	0.083
GSRS	4.91 ± 1.66	4.16 ± 1.18	3.95	0.008
SAQ	45.60 ± 6.94	52.38 ± 7.99	3.02	0.005

Abbreviations: GSRS, Gastrointestinal Symptoms Rating Scale; SAQ, Seattle Angina Questionnaire; Feeding tube use cases: Short term, up to 2 weeks; Middle term, 2 to 4 weeks and Long term, beyond 4 weeks.

more prevalent in the BNFT group compared to the ENFT group. For example, 29.63% of BNFT patients reported shortness of breath, compared to 6.45% in the ENFT group. Similarly, 33.33% of BNFT patients experienced cognitive dysfunction, compared to 9.68% in the ENFT group. These findings indicate that BNFT patients experienced a higher frequency of certain post-COVID-19 symptoms in the short term.

However, no significant differences were found for symptoms such as nausea, diarrhea, or acid reflux, with p-values exceeding 0.05. In the middle-term period (2–4 weeks), the disparities between the two groups became more pronounced. BNFT patients showed significantly higher rates of shortness of breath ($p = 0.002$), cognitive dysfunction ($p = 0.002$), muscle and joint pain ($p = 0.008$), sleep disturbances ($p = 0.000$), and mental health challenges ($p = 0.000$). For example, 57.81% of BNFT patients reported sleep disturbances, compared to 14.29% of ENFT patients. In the long-term period (beyond 4 weeks), symptoms such as shortness of breath ($p = 0.001$), cognitive dysfunction ($p = 0.003$), headaches ($p = 0.000$), and loss of taste or smell ($p = 0.001$) continued to be significantly more common in the BNFT group. The GSRS and SAQ scores also showed significant differences, with BNFT patients reporting higher GSRS scores ($p = 0.008$) and lower SAQ scores ($p = 0.005$), reflecting worse gastrointestinal symptoms and poorer angina-related health outcomes compared to the ENFT group. These results suggest that BNFT patients experienced more severe and persistent post-COVID-19 complications than the ENFT group across several clinical parameters.

Sensitivity Analysis

The sensitivity analysis supported the findings from both the primary and secondary outcomes. For the primary outcomes, the lack of significant differences ($p > 0.05$) in symptoms such as fatigue, cognitive dysfunction, and muscle pain before COVID-19 infection suggests that the BNFT and ENFT groups had comparable baseline health status. Therefore, the observed differences in the secondary outcomes can be attributed to the effects of COVID-19 rather than pre-existing conditions.

For the secondary outcomes, the statistically significant differences ($p < 0.05$) in symptoms such as shortness of breath, cognitive dysfunction, and sleep disturbances, particularly in the BNFT group, indicate that this group experienced a more pronounced post-COVID-19 symptom burden. The analysis also highlighted significant differences in the GSRS and SAQ scores, with BNFT patients experiencing worse gastrointestinal and cardiovascular symptoms. These findings support the conclusion that the BNFT group suffered from more severe post-COVID-19 complications, and the observed differences are unlikely to be confounded by baseline disparities.

Discussion

The primary objective of this study was to compare the effects of BNFT and ENFT placement methods on post-COVID-19 complications in ICU patients requiring enteral feeding. Our key findings indicate that patients in the BNFT group experienced significantly higher rates of post-COVID-19 symptoms, including respiratory, neurological, musculoskeletal, and psychological complications, compared to the ENFT group.

Previous research has highlighted the challenges of blind nasogastric tube placement, including misplacement and increased risk of complications.[25–27] Studies have also reported that endoscopy-guided placement improves accuracy and reduces complications.[10,27] Our findings align with these studies, demonstrating that ENFT placement is associated with better outcomes in post-COVID19 ICU patients. The differences observed may be due to the precise placement and reduced mucosal trauma associated with endoscopic guidance. The differences in outcomes between the BNFT and ENFT groups in post-COVID-19 ICU patients may be attributed to the increased accuracy and reduced complications associated with endoscopy-guided nasojejunal tube placement. ENFT placement allows for precise positioning of the feeding tube within the gastrointestinal tract, reducing the risk of misplacement into the lungs or esophagus, which is a common issue with blind placement. This precision minimizes mucosal trauma, irritation, and inflammation, which can lead to complications such as infection, bleeding, or even tube dislodgment. By avoiding these complications, ENFT provides a more stable and effective means of delivering enteral nutrition, ensuring that patients receive the necessary nutrients to support recovery, particularly in a vulnerable post-COVID-19 population. The reduced incidence of mechanical and gastrointestinal complications in the ENFT group likely contributed to their better post-COVID-19 outcomes, as seen in the reduced rates of fatigue, shortness of breath, and cognitive dysfunction in this group.

Furthermore, the findings suggest that the use of ENFT for more than four weeks may promote better nutrition uptake, which is critical for long-term recovery in post-COVID-19 patients. Proper placement ensures that the enteral nutrition is delivered directly to the jejunum, allowing for more efficient absorption of nutrients. This is particularly important in critically ill patients, such as those recovering from COVID-19, who often suffer from malnutrition and muscle wasting. By improving nutritional delivery, ENFT may help mitigate the inflammatory response, reduce catabolism, and support immune function, which can significantly affect post-COVID-19 complications. Enhanced nutrition uptake may also contribute to improved gastrointestinal function, as reflected in the lower GSRS scores observed in the ENFT group, indicating fewer gastrointestinal symptoms such as reflux, nausea, and diarrhea, which often occur in post-COVID persons.[28,29] In turn, better nutrition and fewer gastrointestinal complications may lead to an overall reduction in post-COVID-19 symptom burden and a faster recovery trajectory. The secondary outcomes evaluated more than six months post-COVID-19 infection highlighted significant differences in SAQ scores between the BNFT and ENFT groups, with BNFT patients reporting lower SAQ scores (Table 5). This indicates poorer angina-related health outcomes, characterized by greater symptom burden, reduced physical function, and diminished quality of life due to angina in the BNFT group compared to the ENFT group. With an SAQ summary score <75 suggesting significant angina burden, these findings underscore that BNFT patients experienced more severe and persistent cardiovascular complications in the long-term period (beyond 4 weeks) post-COVID-19, aligning with broader evidence of worse clinical outcomes in this group.

Potential Applications

The potential application of this study lies in the optimization of enteral feeding practices in ICU settings, particularly for post-COVID-19 patients who are vulnerable to long-term complications. By demonstrating the advantages of ENFT placement over BNFT, this research provides evidence to support the wider adoption of endoscopy-guided methods in critical care units. Hospitals and healthcare providers could implement ENFT as a standard practice to improve patient

outcomes, reduce the risk of complications such as respiratory and gastrointestinal issues, and enhance overall recovery for patients requiring prolonged enteral nutrition. Additionally, these findings may guide future protocols and training in critical care to prioritize safer feeding tube placement techniques, ultimately improving post-ICU recovery trajectories.

Strengths and Limitations

Strengths of this study include a sizable sample size and well-matched baseline characteristics, enhancing the validity of the comparisons. However, limitations include its retrospective design and the potential for unmeasured confounding variables. Additionally, the study was conducted in a single center, which may limit generalizability. Future research should consider multicenter prospective studies to validate these findings.

Future Research Directions

Further investigation is needed to explore the long-term effects of feeding tube placement methods on patient outcomes post-COVID-19. Prospective randomized controlled trials could provide more definitive evidence. Additionally, studies examining the cost-effectiveness of ENFT placement and its impact on healthcare resources would be valuable.

Conclusions

In summary, ENFT placement appears to offer significant benefits over BNFT in reducing post-COVID-19 complications among ICU patients. These findings underscore the importance of utilizing endoscopy-guided techniques to enhance patient recovery and outcomes. Implementing ENFT placement in critical care settings may have a substantial positive impact on patient health and resource utilization.

Data Sharing Statement

Data are available upon reasonable request from the corresponding author.

Author Contributions

Yuequn Chen (Conceptualization; Investigation; Writing – Original Draft; Writing – Review & Editing), Guiqiong Wu (Data Curation; Formal Analysis; Validation; Writing – Review & Editing), Chaojun Qu (Methodology; Software; Visualization; Writing – Original Draft; Writing – Review & Editing), Zimao Ye (Resources; Project Administration; Supervision; Writing – Review & Editing), Yihao Kang (Funding Acquisition; Supervision; Writing – Review & Editing), and Xin Tian (Methodology; Software; Writing – Review & Editing). All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

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