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Economic consequences when enteral tube feeding intolerance causes unplanned discontinuation in hospitalized older patients with gastroesophageal reflux disease

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SUMMARY

Background & aims: Enteral tube feeding intolerance (ETFI) is a common complication in older patients with gastroesophageal reflux disease (GERD), often leading to unplanned discontinuation of nutritional support. While the clinical consequences of ETFI are well-documented, its economic impact on hospital operations remains unclear. This study aimed to evaluate the financial consequences of ETFI-related discontinuation of enteral nutrition in hospitalized older patients with GERD, focusing on changes in medical resource allocation and hospital revenue under Japan's hybrid reimbursement system.

Methods: A retrospective observational study was conducted using patient-level data from a long-term care ward in Japan between April 2018 and March 2021. Patients who initiated enteral tube feeding were categorized based on whether enteral feeding was discontinued due to intolerance. Medical claims data were analyzed to calculate fee-for-service (FFS) and fixed payment system (FPS) charges, unreimbursed medical charges (i.e., revenue loss under FPS), and inpatient living care expenses. Hospital loss simulations were performed based on discontinuation rates and patient characteristics.

Results: Among 149 patients, 23.5 % experienced ETFI-related discontinuation. These patients had significantly lower BMI and shorter feeding durations. Discontinuation was associated with increased unreimbursed medical charges (median JPY +2288/day (USD +15.2/day, USD 1.0 = JPY 150.80) at 1 week post-discontinuation) and decreased living care revenue (median JPY −1179/day (USD −7.82/day)). Multivariate analysis identified ETFI and low BMI (<17.4) as independent predictors of increased hospital revenue losses. Simulations estimated a total loss of JPY 248,000 (USD 1644.56) per 10 hospitalized older patients with GERD over 4 weeks, with greater losses observed in low-BMI patients and those receiving polymeric formulas.

Conclusion: Unplanned discontinuation of enteral tube feeding due to intolerance in older patients with GERD imposes a substantial economic burden on hospitals, primarily through unreimbursed medical

Abbreviations: ADL, Activities of Daily Living; BMI, Body Mass Index; ETFI, Enteral Tube Feeding Intolerance; FFS, Fee-for-Service; FPS, Fixed Payment System; GERD, Gastroesophageal Reflux Disease; JPY, Japanese Yen; ROC, Receiver Operating Characteristic; USD, United States Dollar.

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charges and reduced living care revenue. Preventive strategies—such as early nutritional intervention and formula selection—may mitigate these losses and support sustainable hospital management.

1. Introduction

Gastroesophageal reflux disease (GERD) is a common disease characterized by heartburn as the primary symptom, and it is associated with risks such as dysphagia, vomiting, and delayed gastric emptying [1]. The prevalence of GERD increases significantly in the older people [2]. Nutritional management using tube feeding is also more frequently required in older adults [3]. In this population, GERD-related symptoms such as vomiting and delayed gastric emptying may contribute to the development of enteral tube feeding intolerance (ETFI) [4]. ETFI frequently leads to unplanned discontinuation of nutritional support, which can severely impact patients' nutritional status and affect patient clinical outcomes [5,6]. Our previous study identified several clinical factors including nutritional status and laboratory parameters that may serve as predictive factors for ETFI-related discontinuation [7]. Although previous studies have examined the clinical impact of ETFI, the economic burden on hospital operations has received limited attention.

Parallel to these clinical concerns, demographic and institutional pressures are mounting. The aging population leads to increased healthcare needs, which in turn drives up medical costs and contributes to a shortage of healthcare workers, thereby negatively impacting the sustainability of healthcare service provision [8,9]. The shortage of healthcare workers negatively impacts the performance of hospital facilities [10]. In Japan as well, the recent rise in inflation rates and wage increases due to healthcare worker shortages have worsened the financial situation of hospitals [11,12].

In this context, ETFI may not only compromise patient outcomes but also impose a substantial economic burden on hospitals. Japan employs a hybrid reimbursement hospital system which combines fixed payment system (FPS) and fee-for-service system (FFS) [13]. In long-term care wards, FPS is the primary reimbursement method, while specific procedures (e.g., surgery, anesthesia, rehabilitation, etc.) reimbursed under FFS. Under FPS, hospitals receive fixed per-diem payments based on patients' medical care needs and activities of daily living (ADL) levels, regardless of the actual resources consumed. This structure implies that hospitals must absorb the cost of additional interventions arising from complications without receiving proportional reimbursement. For instance, if enteral nutrition is discontinued due to ETFI, hospitals may need to implement alternative nutritional strategies, such as parenteral nutrition, and provide additional clinical management. These interventions often fall outside the scope of FPS reimbursement, leading to increased resource utilization without corresponding revenue. Consequently, ETFI not only threatens patient outcomes but also risks creating a financial imbalance—particularly in long-term care settings where fixed per-diem payments are standard. This mismatch between resource input and reimbursement may exacerbate the economic strain on hospitals operating under the current payment framework.

Therefore, this retrospective observational study aimed to evaluate the economic consequences of ETFI-related discontinuation of enteral nutrition in hospitalized older patients, especially those with GERD who may be at increased risk of developing enteral tube feeding intolerance. Specifically, we analyzed changes in medical resource allocation and estimated hospital revenue losses under Japan's reimbursement system.

2. Material and methods

2.1. Study design, setting, and population

This retrospective observational study was conducted at a long-term care ward in Japan, targeting older patients with GERD who initiated enteral tube feeding between April 2018 and March 2021. Patients diagnosed with GERD were identified based on information documented in their medical records. Eligible patients were those who began enteral tube feeding during hospitalization. Exclusion criteria included the following: patients who (i) were able to ingest food orally at the initiation of enteral nutrition, (ii) received enteral tube feeding for less than five days, or (iii) could not be followed up within one month for reasons unrelated to ETFI.

2.2. Data collection and economic metrics

Anonymized patient-level claims data were extracted, including medical charges, procedure codes, implementation dates, quantities of services, pharmaceuticals, and medical materials. The following economic indicators were calculated (Supplementary Fig. 1):

- FFS-based charges: Total theoretical charges if all services were reimbursed under FFS.
- FPS-based charges: Actual hospital revenue under FPS.
- Unreimbursed medical charges: The difference between FFS and FPS charges, representing revenue loss.
- Inpatient living care fees: Daily charges for meals and housing.

Data on discontinuation due to intolerance and associated clinical symptoms were extracted from medical records. For patients with ETFI-related discontinuation, data were collected from 7 days before to 28 days after discontinuation. For patients without discontinuation, a matched 5-week period starting from day 24 post-tube feeding initiation was used.

All cost conversions from Japanese yen to US dollars in this study were based on the exchange rate as of August 1, 2025, with USD 1.0 equivalent to JPY 150.80.

2.3. Simulation of Hospital Losses

To estimate the financial impact of ETFI, simulations were conducted assuming a cohort of 10 patients. Weekly changes in unreimbursed medical charges and inpatient living care fees were calculated relative to the week prior to discontinuation. These were aggregated over four weeks and multiplied by the discontinuation rate.

Estimated unreimbursed medical charges under the fixed payment system were calculated as follows:

Estimated total unreimbursed medical charges = Σ (ΔUnreimbursed medical charges_week_n × 7 days) × 10 patients × ETFI discontinuation rate,

where Δunreimbursed medical charges_week_n represents the weekly change in unreimbursed charges compared to the week prior to discontinuation (n = 1 to 4).

Estimated total inpatient living care fees were calculated in the same manner.

2.4. Statistical analysis

Continuous variables were expressed as mean ± standard deviation or median with interquartile range, depending on distribution. Student's t-test or Wilcoxon test was used for comparisons. Categorical variables were expressed as counts (%), and Fisher's exact probability test was used for comparisons. For the analysis of medical reimbursement fees, weekly average values were calculated for each patient. In the discontinuation group, three time points were defined:

- **t1**: from 7 days to 1 day before discontinuation
- **t2**: from the day of discontinuation to 6 days after
- **t3**: from 22 to 28 days after discontinuation

In the non-discontinuation group, matched time points were defined as:

- **t1**: from 24 to 30 days after initiation of enteral feeding
- **t2**: from 31 to 37 days after initiation
- **t3**: from 53 to 59 days after initiation

Within-group comparisons across the three time points were performed using the Friedman test. For multiple comparisons between t1 vs. t2 and t1 vs. t3, the Wilcoxon signed-rank test with Bonferroni correction was applied. The Hodges–Lehmann estimator was calculated to evaluate median differences. Between-group comparisons (discontinuation vs. non-discontinuation) at each time point were performed using the Aligned Rank Transform ANOVA. When significant interactions were observed, post hoc comparisons at each time point were conducted using the Wilcoxon rank-sum test and the Hodges–Lehmann estimator.

To identify factors associated with changes in unreimbursed medical fees, univariate and multivariate ordinal regression analyses were conducted. The dependent variable was the change in unreimbursed medical charges, and explanatory variables included patient background characteristics such as ETFI discontinuation, BMI, age, gender, Medical classification, ADL classification, nutrition route, and type of formula. Medical classification and ADL classification are standardized categories in the Japanese reimbursement system that comprehensively reflect patient complexity, including overall medical needs, the presence of specific comorbidities defined under the system, and level of dependency.

All statistical analyses were performed using R (version 4.2.0). In all tests, p-values less than 0.05 were considered statistically significant.

2.5. Ethical considerations

This study was approved by the Ethics Review Committee of the Kinshu-kai on July 30, 2022 (2024-13). All procedures were conducted in accordance with the Declaration of Helsinki of 1975 (revised in 2000). Patient data were anonymized and managed following the Personal Information Protection Act and ethical guidelines to ensure confidentiality. Since this study was a retrospective trial, informed consent was not obtained; however, an opt-out procedure was implemented to allow patients to refuse participation.

3. Results

3.1. Incidence and characteristics of ETFI-related discontinuation

Among the 149 hospitalized older patients with GERD who initiated enteral tube feeding for at least 5 days, 23.5 % (n = 35) experienced unplanned discontinuation due to intolerance (Fig. 1). The reasons for discontinuation due to intolerance were vomiting/reflux (65.7 %) and diarrhea (34.2 %) (Table 1). These patients had significantly shorter feeding durations compared to those who continued feeding (15.3 ± 7.0 vs. 26.1 ± 7.6 days, $p < 0.001$).

Patient characteristics comparison revealed that those who experienced ETFI-related discontinuation had significantly lower BMI (16.9 ± 3.2 vs. 18.5 ± 4.0 kg/m^2, p = 0.025). Given this significant association and its potential impact on economic outcomes, we further investigated BMI as a stratification factor for economic analysis. Receiver operating characteristic (ROC) analysis and Kaplan–Meier survival analysis were conducted to determine an optimal cutoff value for predicting ETFI-related discontinuation. A BMI threshold of 17.4 was identified, with a sensitivity of 0.69 and specificity of 0.60 (Supplementary Fig. 2). Patients were subsequently stratified into lower BMI (<17.4) and non-lower BMI (≥17.4) groups, as summarized in Supplementary Table 1. Although the primary economic evaluation was conducted on the overall cohort (see "Economic Impact of ETFI-Related Discontinuation"), this threshold was subsequently applied in multivariate models (see "Analysis of factors affecting changes in unreimbursed medical charges") and subgroup simulations (see Table 5B in "Simulation of Hospital Losses") to explore the differential financial impact in patients with low BMI.

3.2. Economic impact of ETFI-related discontinuation

In patients who experienced ETFI-related discontinuation, FFS-based charges increased significantly in the week following discontinuation (t2) compared to the week prior (t1), with a Hodges–Lehmann estimated median difference of JPY +1125/day (USD +7.46/day) (Table 2, Supplementary Fig. 3). In contrast, FPS-based charges remained unchanged. As a result, unreimbursed medical charges—defined as the difference between FFS-based and FPS-based charges—increased significantly after discontinuation. The Hodges–Lehmann estimated median differences were JPY +2288/day (USD +15.17/day) at t2 and JPY +1349/day (USD +8.95/day) at four weeks post-discontinuation (t3). Conversely, inpatient living care charges also declined significantly in the discontinuation group, with an estimated median decrease of JPY −1179/day (USD −7.82/day) at t2 and JPY −1339/day (USD −8.88/day) at t3. Inpatient living care charges in Japan's long-term care wards consist of meal fees and utility costs. When enteral nutrition is discontinued, meal provision is no longer required, resulting in a loss of meal fee revenue and thus a reduction in inpatient living care charges. In contrast, no significant changes were observed in any of these metrics in the non-discontinuation group.

Between-group comparisons further confirmed that patients with ETFI-related discontinuation incurred significantly higher unreimbursed medical charges and lower living care charges than those who continued feeding. The Hodges–Lehmann estimated median differences in unreimbursed charges between the two groups were JPY +2841/day (USD +18.84/day) at t2 (95 % CI: 966 to

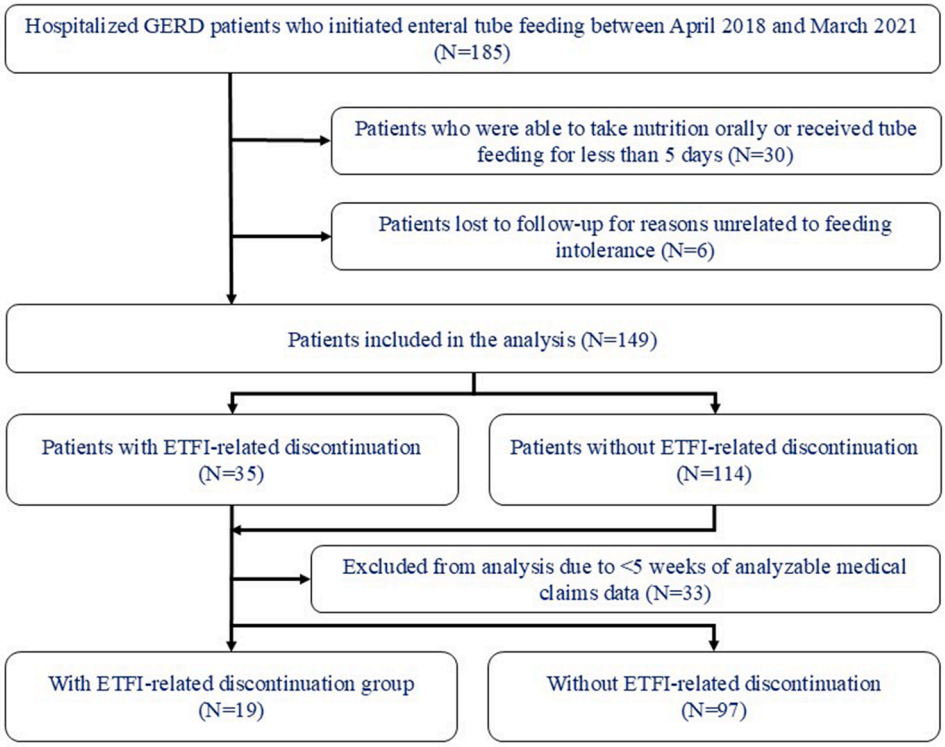

Fig. 1. Patient Flow Diagram
Flowchart of patient selection and classification.

4404) and JPY +2200/day (USD +14.59/day) at t3 (95 % CI: 594 to 3467). For inpatient living care charges, the differences were JPY −1143/day (USD −7.58/day) at t2 (95 % CI: −1234 to −1020) and JPY −1179/day (USD −7.82/day) at t3 (95 % CI: −1429 to −377).

A breakdown of medical procedures revealed that the increase in unreimbursed medical charges was primarily driven by an increase in intravenous injections—including parenteral nutrition agents—and diagnostic examinations, both of which are bundled under the fixed payment system and thus not separately reimbursed (Table 3). In contrast, rehabilitation services, which are reimbursed on a fee-for-service basis, decreased following ETFI-related discontinuation. Additionally, the number of prescribed drug types increased from a median of 7.0 in the week prior to discontinuation to 11.0 in the week immediately following, and remained elevated at 10.0 even four weeks later.

Table 1
Baseline characteristics of the study population.

Item	All (N = 149)	Patients with ETFI-related discontinuation (N = 35)	Patients without ETFI-related discontinuation (N = 114)	P-value
Age, mean ± SD	81.9 ± 9.7	82.9 ± 7.8	81.6 ± 10.2	0.588
Male, N (%)	53 (35.6)	17 (48.6)	36 (31.6)	0.073
Body Mass index (kg/m^2), mean ± SD	18.2 ± 3.9	16.9 ± 3.2	18.5 ± 4.0	0.025
Reason for tube feeding discontinuation				
Vomiting/reflux, N (%)	23 (15.4)	23 (65.7)	0 (0)	
Diarrhea, N (%)	12 (8.1)	12 (34.3)	0 (0)	
Duration of tube feeding (days), mean ± SD	23.5 ± 8.7	15.3 ± 7.0	26.1 ± 7.6	<0.001
Medical classification, N (%)				0.931
Grade 1	61 (40.9)	14 (40.0)	47 (41.2)	
Grade 2	66 (44.3)	15 (42.9)	51 (44.7)	
Grade 3	22 (14.8)	6 (17.1)	16 (14.0)	
Activity daily living classification, N (%)				0.061
Grade 1	44 (29.5)	10 (28.6)	34 (29.8)	
Grade 2	14 (9.4)	7 (20.0)	7 (6.1)	
Grade 3	91 (61.1)	18 (51.4)	73 (64.0)	
Route of nutritional administration				0.833
Gastrostomy	41 (27.5)	9 (25.7)	32 (28.1)	
Nasogastric tube	108 (72.5)	26 (74.3)	82 (71.9)	
Enteral formula				0.799
Oligomeric formula, N (%)	26 (17.4)	5 (14.3)	21 (18.4)	
Polymeric formula, N (%)	123 (82.6)	30 (85.7)	93 (81.6)	

ETFI: Enteral Tube Feeding Intolerance.
Values are presented as mean ± standard deviation for continuous variables and number (%) for categorical variables.
p-values were calculated using Student's t-test for continuous variables and Fisher's exact test for categorical variables.
“Grade” classifications for medical and ADL levels are based on Japan's long-term care reimbursement system.

3.3. Analysis of factors affecting changes in unreimbursed medical charges

Multivariate regression analysis identified ETFI-related discontinuation (adjusted estimate: +29.6, $p < 0.001$) and low BMI (<17.4; adjusted estimate: +13.6, $p = 0.025$) as independent predictors of increased unreimbursed medical costs in the first week post-discontinuation (Table 4). At four weeks, only ETFI remained a significant predictor (adjusted estimate: +24.5, $p = 0.003$).

Table 2
Economic impact of ETFI discontinuation: Changes in charges.

Group	Economic indicators	t1	t2	t2 vs t1 P-value	Median Difference (t2–t1), (95 % CI)	t3	t3 vs t1 P-value	Median Difference (t3–t1), (95 % CI)
Patients with ETFI-related discontinuation	FFS-based charges, JPY/day	23,220 (22,795, 25,979)	25,610 (23,754, 29,005)	0.006	1125 (255–3420)	26,461 (21,864, 27,033)	0.664	788 (-1214 – 2624)
(N = 19)	FPS-based charges, JPY/day	21,587 (19,859, 23,959)	21,731 (19,991, 23,398)	1.000	−41 (-1704 – 1240)	21,199 (20,055, 24,051)	0.788	−416 (-1973 – 735)
	Unreimbursed medical charges, JPY/day	1769 (1196, 2916)	4844 (2691, 6326)	0.002	2288 (812–3564)	3643 (2466, 5757)	0.028	1349 (143–2706)
	Inpatient living care charges, JPY/day	1898 (1775, 1898)	684 (541, 791)	<0.001	−1179 (−1321 to −893)	398 (398, 1454)	0.001	−1339 (−1500 to −918)
Patients without ETFI-related discontinuation	FFS-based charges, JPY/day	22,487 (20,713, 24,964)	22,927 (20,160, 25,220)	1.000	41 (-596 – 626)	21,807 (20,230, 24,499)	0.238	−483 (-1256 – 212)
(N = 97)	FPS-based charges, JPY/day	20,899 (18,890, 24,440)	20,847 (18,250, 23,510)	1.000	−100 (-796 – 549)	20,623 (18,451, 22,471)	0.115	−534 (-1322 – 116)
	Unreimbursed medical charges, JPY/day	1296 (670, 2644)	1541 (1040, 2579)	0.644	93 (-134 – 387)	1336 (250, 2377)	1.000	24 (-251 – 281)
	Inpatient living care charges, JPY/day	1898 (1775, 1898)	1898 (1775, 1898)	1.000	−13 (-384 – 49)	1898 (1775, 1898)	0.660	−72 (-687 – 60)

ETFI: Enteral Tube Feeding Intolerance, FFS: Fee-for-service payment based, FPS: fixed payment system base.
t1: The 7-day period prior to ETFI-related discontinuation (or the equivalent reference point for patients without discontinuation).
t2: The 7-day period immediately following ETFI-related discontinuation (or the equivalent reference point).
t3: The 7-day period beginning 4 weeks after ETFI-related discontinuation (or the equivalent reference point).
p-values were calculated using the Wilcoxon signed-rank test and adjusted using the Bonferroni method where applicable.
Median differences were estimated using the Hodges–Lehmann estimator and adjusted using the Bonferroni method where applicable.

Table 3
Breakdown of medical procedures associated with economic impact of ETFI discontinuation.

Medical Procedure	FFS/FPS	Unit	t1	t2	t2 vs t1 P-value	Median Difference (t2–t1), (95 % CI)	t3	t3 vs t1 P-value	Median Difference (t3–t1), (95 % CI)
Oral drugs	FPS	JPY/day	1322 (661, 3891)	1953 (688, 3836)	1.000	−19 (-763 – 1289)	825 (132, 2306)	0.972	−155 (-1290 – 6619)
Topical drugs	FPS	JPY/day	0 (0, 0)	0 (0, 0)	0.742	3759 (3759–3759)	0 (0, 0)	0.402	708 (-106 – 3452)
Subcutaneous/ intramuscular injection	FPS	JPY/day	0 (0.0)	0 (0, 0)	1.000	−156 (-579 – 103)	0 (0, 0)	1.000	−173 (-494 – 81)
Intravenous injection	FPS	JPY/day	44 (0, 2282)	12,197 (8938, 14,142)	<0.001	9950 (7587–12,197)	7523 (4199, 13,365)	<0.001	7709 (4423–12,228)
Drug management/ prescription dosage	FPS	JPY/day	70 (70, 80)	70 (70, 80)	1.000	9 (-59 – 235)	70 (70, 130)	0.938	45 (-60 – 256)
Treatment	FPS	JPY/day	1341 (1080, 4398)	4585 (1573, 6345)	0.123	1520 (-76 – 2800)	4653 (1080, 5710)	0.374	1270 (-579 – 2986)
Examination	FPS	JPY/day	236 (0, 806)	817 (274, 1791)	0.026	719 (144–1551)	720 (208, 990)	0.133	376 (-148 – 822)
Imaging diagnosis	FPS	JPY/day	0 (0, 0)	300 (0, 400)	0.218	400 (-150 – 1557)	0 (0, 0)	1.000	−332 (-700 – 1457)
Rehabilitation	FFS	JPY/day	1400 (0, 3486)	0 (0, 2265)	0.010	−1396 (−3346 to −414)	257 (0, 3325)	0.137	−993 (-2593 – 189)
Hospitalization fees	FPS	JPY/day	19,330 (17,180, 20,090)	20,010 (17,930, 20,204)	1.000	−250 (-1193 – 1531)	20,040 (16,205, 20,125)	0.574	−838 (-2139 – 697)
Number of types of prescription drugs	–	Number of types/week	7.0 (4.5, 9.5)	11.0 (10.0, 16.5)	<0.001	6.0 (3.5–9.0)	10.0 (7.5, 11.5)	0.017	3.0 (0.5–6.0)

N = 19.
Medical procedures were categorized based on EF file data codes and grouped by route of administration or service type (e.g., intravenous, oral, diagnostic imaging etc.).
ETFI: Enteral Tube Feeding Intolerance, FFS: Fee-for-service payment based, FPS: fixed payment system based.
t1: the 7-day period prior to ETFI-related discontinuation.
t2: the 7-day period immediately following discontinuation.
t3: the 7-day period beginning 4 weeks after discontinuation.
p-values were calculated using the Wilcoxon signed-rank test and adjusted using the Bonferroni method where applicable.
Median differences were estimated using the Hodges–Lehmann estimator and adjusted using the Bonferroni method where applicable.

Table 4
Predictors of Increased Unreimbursed Medical charges: Rank-Transformed Linear Regression Analysis.

Independent variable	t2-t1 crude			t2-t1 adjusted			t3-t1 crude			t3-t1 adjusted		
	Estimate	SE	P-value	Estimate	SE	P-value	Estimate	SE	P-value	Estimate	SE	P-value
Gender, male	8.06	6.41	0.211	5.55	6.42	0.389	3.32	6.47	0.608	−0.98	6.51	0.881
Age: 1 year	0.01	0.32	0.972	−0.13	0.31	0.671	−0.26	0.32	0.419	−0.54	0.31	0.083
ETFI-related discontinuation	35.12	7.71	<0.001	29.62	8.03	<0.001	26.03	8.05	0.002	24.53	8.15	0.003
Lower BMI (BMI <17.4)	19.33	5.94	0.001	13.64	5.99	0.025	13.64	6.09	0.027	7.57	6.08	0.215
Medical classification												
Grade 2, vs Grade 1	5.13	6.71	0.446	−2.98	9.46	0.754	15.76	6.59	0.019	5.13	9.60	0.594
Grade 3, vs Grade 1	14.44	9.15	0.117	2.20	11.06	0.843	18.14	8.99	0.046	3.50	11.22	0.756
ADL classification												
Grade 2, vs Grade 1	6.86	17.39	0.694	8.27	19.22	0.668	7.88	16.94	0.643	5.33	19.51	0.785
Grade 3, vs Grade 1	13.93	6.72	0.040	13.66	9.87	0.169	21.82	6.54	0.001	19.31	10.02	0.057
Nutrition route, Nasogastric	−1.73	6.82	0.800	2.03	6.53	0.756	0.46	6.84	0.947	3.45	6.63	0.603
Liquid diet, polymeric formula	−3.84	7.91	0.628	−5.98	7.48	0.426	8.13	7.90	0.305	8.61	7.59	0.259

SE: Standard error, ETFI: Enteral Tube Feeding Intolerance, BMI: Body Mass Index, ADL: Activities of daily living.
Rank-transformed linear regression was used to account for non-normal distribution of outcome variables.

3.4. Simulation of Hospital Losses

Using weekly changes in unreimbursed medical charges and inpatient living care charges derived from Supplementary Table 2, simulations estimated that ETFI-related discontinuation leads to a cumulative hospital loss of approximately JPY 248,000 (USD 1644.56) per 10 hospitalized older patients with GERD over a four-week period (Table 5A).

Subgroup analyses revealed greater financial losses in the following populations:

- Discontinuation due to vomiting/reflux: Associated with a loss of approximately JPY 177,000 (USD 1173.74), which was notably higher than the loss from diarrhea-related discontinuation (JPY 59,000 (USD 391.25)), due to more unreimbursed medical charges and reduced living care revenue.
- Patients receiving polymeric formula: Incurred an estimated loss of JPY 299,000 (USD 1982.76), compared to JPY 80,000 (USD 530.50) for those receiving oligomeric formula.
- Patients with lower BMI (<17.4): Demonstrated the highest estimated hospital loss of approximately JPY 343,000 (USD 2274.54) per 10 hospitalized older patients with GERD over four weeks (Table 5B). Importantly, this subgroup overlapped substantially with those experiencing vomiting/reflux-related discontinuation and those receiving polymeric and oligomeric formulas.

4. Discussion

While our study was conducted in Japan, the findings may have broader implications for aging societies worldwide. As healthcare systems globally face similar challenges of rising costs and resource constraints, understanding the economic burden of common complications like enteral tube feeding due to intolerance (ETFI) becomes increasingly important for sustainable healthcare delivery. In this context, this study provides novel insights into the economic burden associated with unplanned discontinuation of ETFI in hospitalized older patients with gastroesophageal reflux disease (GERD). Using real-world claims data from a long-term care ward in Japan, we demonstrated that ETFI leads to a significant increase in unreimbursed medical procedures and a concurrent decline in inpatient living care revenue for hospitals. These findings highlight the dual clinical and financial consequences of ETFI and underscore the need for preventive strategies to support sustainable hospital operations.

4.1. The impact of tube feeding discontinuation due to intolerance on hospital management

While previous studies have focused on the clinical outcomes of ETFI [5], our analysis reveals that the financial impact on hospitals is substantial. The estimated loss of approximately JPY 250,000 (USD 1657.82) per 10 hospitalized older patients with GERD over four weeks reflects a marked increase in unreimbursed medical charges and reduced living care revenue. Notably, these losses persisted beyond four weeks, suggesting a prolonged economic strain. Moreover, the shift from enteral to parenteral nutrition and the increased use of bundled services such as intravenous injections and diagnostic tests—none of which are separately reimbursed under the fixed payment system (FPS)—further exacerbated the financial burden. In contrast, rehabilitation services, which are reimbursed under the fee-for-service (FFS) basis even under FPS in the long-term care wards in Japan, declined following ETFI, contributing to additional revenue loss and potentially compromising patient functional outcomes [14].

These findings are particularly relevant in the context of Japan's aging population and rising hospital operating costs. The mismatch between resource utilization and reimbursement under the hybrid FPS/FFS system may threaten the financial viability of long-term care facilities. Our results suggest that ETFI not only affects patient care but also undermines the economic sustainability of healthcare institutions.

Furthermore, discontinuation of enteral tube feeding due to intolerance is likely to increase the workload of healthcare professionals, potentially leading to higher labor costs and staff fatigue. In addition, the need for increased use of supportive care items—such as diapers, bed linens, and infection control supplies—may further elevate hospital operating costs. Since these items are typically not reimbursed under Japan's medical fee system, they represent an additional out-of-pocket burden for hospitals. These indirect costs, though not captured in our quantitative analysis, may further exacerbate the financial strain associated with ETFI.

These financial impacts may compromise hospital performance and, in the long term, threaten the sustainable provision of medical services. In light of rising operational costs and declining revenues across healthcare institutions, our findings offer timely insights for discussions on the sustainability of healthcare delivery systems.

4.2. Risk stratification and preventive strategies

Our multivariate analysis identified low BMI (<17.4) as an independent predictor of increased unreimbursed medical charges

Table 5A
Estimated 4-week hospital revenue loss per 10 GERD patients following ETFI-Related tube feeding discontinuation.

Population	Calculation assumptions	Estimated unreimbursed medical charges under FPS	Estimated inpatient living care charges	Estimated total losses for hospitals
Total	Target patients: 10 GERD patients who started tube feeding Period: 4 weeks Discontinuation rate due to intolerance: 23.5 % (Supplementary Table 1) Financial impact components: -Changes in unreimbursed medical charges: Condition A in Supplementary Table 2 -Changes in inpatient living care charges: Condition F in Supplementary Table 2	¥155,716	¥91,939	¥247,655
Simulation by reason for discontinuation				
Discontinuation due to vomiting/reflux	Target patients: 10 GERD patients who started tube feeding Period: 4 weeks Discontinuation rate due to intolerance: 15.4 % (Supplementary Table 1) Financial impact components: -Changes in unreimbursed medical charges: Condition B in Supplementary Table 2 -Changes in inpatient living care charges: Condition G in Supplementary Table 2	¥118,321	¥59,010	¥177,331
Discontinuation due to diarrhea	Target patients: 10 GERD patients who started tube feeding Period: 4 weeks Discontinuation rate due to intolerance: 8.1 % (Supplementary Table 1) Financial impact components: -Changes in unreimbursed medical charges: Condition C in Supplementary Table 2 -Changes in inpatient living care charges: Condition H in Supplementary Table 2	¥34,281	¥24,375	¥58,656
Simulation by type of liquid diet				
Oligomeric formula	Target patients: 10 GERD patients who started tube feeding with oligomeric formula Period: 4 weeks Discontinuation rate due to intolerance: 19.2 % (Supplementary Table 1) Financial impact components: -Changes in unreimbursed medical charges: Condition D in Supplementary Table 2 -Changes in inpatient living care charges: Condition I in Supplementary Table 2	¥43,841	¥36,490	¥80,331
Polymeric formula	Target patients: 10 GERD patients who started tube feeding with polymeric formula Period: 4 weeks Discontinuation rate due to intolerance: 24.4 % (Supplementary Table 1) Financial impact components: -Changes in unreimbursed medical charges: Condition E in Supplementary Table 2 -Changes in inpatient living care charges: Condition J in Supplementary Table 2	¥202,142	¥96,536	¥298,678
Difference		(¥158,301)	(¥60,047)	(¥218,347)

Estimates are based on a 4-week simulation for a cohort of 10 hospitalized older patients with GERD. Losses include unreimbursed medical procedures and reductions in living care revenue, derived from Supplementary Table 2.

in the first week following ETFI-related discontinuation, even after adjusting for ETFI itself. This finding aligns with previous research suggesting that malnutrition is a key risk factor for feeding intolerance [7]. Notably, according to the Global Leadership Initiative on Malnutrition (GLIM) criteria, a BMI reference value of 17.8 kg/m^2 has been reported for classifying the severity of malnutrition in older Asian patients [15]. In our study, the optimal BMI cut-off for predicting ETFI-related discontinuation, determined by ROC analysis, was 17.4 kg/m^2. The close proximity of these values supports the clinical relevance of our cohort-specific threshold for this population. We emphasize, however, that 17.4 kg/m^2 is a data-driven, cohort-specific threshold that serves as a complementary indicator rather than a replacement for established BMI reference values. Furthermore, subgroup simulations revealed that patients with low BMI incurred the highest estimated losses (JPY 343,000 (USD 2274.54) per 10 hospitalized older patients with GERD), particularly when ETFI was triggered by vomiting/reflux. These results emphasize the importance of early nutritional interventions aimed at preventing weight loss and improving baseline nutritional status in older patients with GERD. This underscores the value of nutritional assessment and appropriate intervention not only to improve patient outcomes but also to reduce hospital losses. Specifically, conducting nutritional assessment at the time of hospital admission allows for early identification of patients at risk of malnutrition, enabling timely intervention. Such strategies may offer dual benefits for both

Table 5B
Estimated 4-week hospital revenue loss per 10 GERD patients with lower BMI following ETFI-Related tube feeding discontinuation.

Population	Calculation assumptions	Estimated unreimbursed medical charges under FPS	Estimated inpatient living care charges	Estimated total losses for hospitals
Total	Target patients: 10 weight-loss GERD patients who started tube feeding Period: 4 weeks Discontinuation rate due to intolerance: 32.4 % (Supplementary Table 1) Financial impact components: -Changes in unreimbursed medical charges: Condition A′ in Supplementary Table 2 -Changes in inpatient living care charges: Condition F′ in Supplementary Table 2	¥215,188	¥127,983	¥343,171
Simulation by reason for discontinuation				
Discontinuation due to vomiting/reflux	Target patients: 10 weight-loss GERD patients who started tube feeding Period: 4 weeks Discontinuation rate due to intolerance: 24.3 % (Supplementary Table 1) Financial impact components: -Changes in unreimbursed medical charges: Condition B′ in Supplementary Table 2 -Changes in inpatient living care charges: Condition G′ in Supplementary Table 2	¥191,550	¥95,154	¥286,704
Discontinuation due to diarrhea	Target patients: 10 weight-loss GERD patients who started tube feeding Period: 4 weeks Discontinuation rate due to intolerance: 8.1 % (Supplementary Table 1) Financial impact components: -Changes in unreimbursed medical charges: Condition C′ in Supplementary Table 2 -Changes in inpatient living care charges: Condition H′ in Supplementary Table 2	¥23,037	¥18,666	¥41,703
Simulation by type of liquid diet				
Oligomeric formula	Target patients: 10 weight-loss GERD patients who started tube feeding with oligomeric formula Period: 4 weeks Discontinuation rate due to intolerance: 25.0 % (Supplementary Table 1) The financial impact of discontinuing tube feeding due to intolerance -Changes in unreimbursed medical charges: Condition D′ in Supplementary Table 2 -Changes in inpatient living care charges: Condition I′ in Supplementary Table 2	¥71,278	¥59,378	¥130,656
Polymeric formula	Target patients: 10 weight-loss GERD patients who started tube feeding with polymeric formula Period: 4 weeks Discontinuation rate due to intolerance: 33.9 % (Supplementary Table 1) The financial impact of discontinuing tube feeding due to intolerance -Changes in unreimbursed medical charges: Condition E′ in Supplementary Table 2 -Changes in inpatient living care charges: Condition J′ in Supplementary Table 2	¥273,963	¥133,908	¥407,871
Difference		(¥202,685)	(¥74,531)	(¥277,215)

Estimates are based on a simulation for 10 hospitalized older patients with GERD and BMI <17.4. Weekly changes in unreimbursed medical charges and living care revenue were derived from Supplementary Table 2.

patients and healthcare institutions, particularly in aging societies where resource optimization is critical.

In addition, our analysis of formula type suggests that the use of oligomeric formulas may mitigate financial losses. Patients receiving polymeric formulas experienced greater rates of ETFI and higher associated costs. Given that whey peptide-based oligomeric formulas have been shown to promote faster gastric emptying and reduce gastrointestinal symptoms [16,17], their use may help prevent ETFI and its downstream economic consequences. Although our study was retrospective and limited in sample size, these findings warrant further investigation in prospective trials.

4.3. Limitations of this study

This study has several limitations. First, its retrospective design may introduce selection and information biases. Second, the analysis was based on data from a single institution, which may limit generalizability. Third, although medical and ADL classifications were included as proxy indicators of patient complexity, individual comorbidities and specific reasons for hospitalization were not separately analyzed, which may lead to residual confounding. Fourth, GERD diagnosis was not uniformly confirmed by endoscopy or pH monitoring in all patients; some diagnoses relied

on clinical judgment and documented medical history, which may introduce misclassification bias. Finally, this study did not assess the effectiveness of specific nutritional management strategies in preventing ETFI-related discontinuation. Future prospective studies should explore the role of appropriate nutritional interventions in reducing both clinical complications and hospital losses.

5. Conclusion

ETFI in hospitalized older patients with GERD imposes a significant economic burden on hospitals, driven by unreimbursed medical charges and reduced living care revenue.

Author contribution

Yukikazu Kamada: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing - review & editing.

Kanako Kawano, Akina Iguchi, Noriko Tominaga, and Masatoshi Inoue: Investigation.

Chisato Okamoto, Ataru Igarashi, and Masafumi Kitakaze: Conceptualization, Methodology, Analysis, Project administration, Resources, Supervision, Validation, Writing - review & editing.

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Conflict of interest

Yukikazu Kamada is an employee of Nestle Health Science. The other authors have no conflicts of interest to disclose.

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During the preparation of this work, the authors used Microsoft Copilot to improve the English language and readability of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Appendix A. Supplementary data

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