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ORIGINAL RESEARCH

# Medication Administration Through Feeding Tubes in a Tertiary Hospital: A Retrospective Observational Study

Yuanchao Zhu, Bolin Zhu, Pengfei Jin

Department of Pharmacy, Beijing Hospital, National Center of Gerontology, Institute of Geriatric Medicine, Chinese Academy of Medical Sciences, Beijing Key Laboratory of Assessment of Clinical Drugs Risk and Individual Application(Beijing Hospital), Beijing, 100730, People's Republic of China

Correspondence: Pengfei Jin, Email j790101@163.com



**Aim:** This study aimed to investigate the prevalence and types of errors associated with oral medication administration via feeding tubes (FTs) in a tertiary hospital in Beijing.

**Methods:** A retrospective observational study was conducted at Beijing Hospital between January 2018 and December 2022. All inpatients aged of 18 and above who received at least one oral medication via FTs were included. Medical records were meticulously collected and analyzed.

**Results:** A total of 7,243 patients were identified as part of the tube feeding group, representing a prevalence rate of 6.26% among hospitalized patients receiving oral medication. Compared to the general hospitalized population, patients in the tube feeding group exhibited a higher proportion of male patients (59.74% vs 48.91%), older age [(68.00±14.99) vs (59.75±16.38)], lower weight [(65.75 ±13.32) vs (67.82±12.72)], increased rates of being bedridden (18.06% vs 5.38%), longer hospital stay [(21.56±28.12) vs (8.88 ±10.38)], and a greater number of prescribed medication types [(51.21±19.37) vs (23.35±15.04)]. On average, patients in the tube feeding group were administered 8.92±6.78 types of oral medications. A significant percentage of patients in the tube feeding group experienced inappropriate medication administration, reaching 65.43%. Among these cases, the rate of inappropriate medication administration for patients receiving nasogastric tube and nasojejunal tube were 64.06% (4186/6535) and 78.11% (553/708), respectively. In total, there were 10,164 instances of inappropriate medication administration, averaging 1.40 times per patient in the tube feeding group. Inappropriate medications included enteric-coated drugs, modified-released, soft capsules, and other non-crushable drugs.

**Conclusion:** Our results Our findings highlight a significant issue of inappropriate medication administration via FTs. Ensuring the accurate administration of orally prescribed medications to patients with FTs is a complex task that requires immediate attention.

**Keywords:** tube feeding, inappropriate medication, medication errors, nasogastric tube, nasojejunal tube

## Introduction

In cases where oral intake is inadequate or contraindicated for various reasons, patients may require alternative forms of nutrition such as enteral nutrition (EN) or parental nutrition (PN).[1] Among these options, EN, employing a feeding tube (FT), is a preferred method for patients facing challenges with nutrition intake. These feeding tubes can be categorized based on their insertion site (oral, nasal), the location of the tube's distal end (gastric, duodenal, or jejunal), and the tube diameter (ranging from 4Fr to 20Fr).

Patients with a feeding tube for nutrition often take oral medications by the same route. Solid dosage forms are often pulverized and mixed with water to facilitate their administration through a FT.[2] However, inappropriate administration via an FT can lead to several complications.[3] Firstly, administering medications to patients receiving continuous enteral feeding may result in gastrointestinal intolerance, decreased bioavailability, adverse drug reactions, or physical incompatibilities.[4] Secondly, crushed tablets are a frequent cause of tube obstruction.[5] Thirdly, grinding mutagenic or

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teratogenic drugs may posed increased exposure risks to healthcare providers.[6] Lastly, it can result in treatment delays, a higher incidence of adverse drug events, and increased economic burdens on patients.

We present the findings of a 5-year retrospective observational study conducted at a tertiary hospital in China. The primary objective was to assess the prevalence and categorize the errors that occurred in the administration of medications to patients reliant on FTs. This study aimed to pinpoint specific areas in which enhancements could be introduced to improve the safety and efficacy of medication delivery.

# Materials and Methods

## Study Population

A retrospective, single-center, observational study was performed in a 1300-bed tertiary hospital between January 2018 and December 2022. The study encompassed all hospitalized individuals aged 18 years or older who had at least one oral medication. Oral medications referred to drugs prescribed for oral administration as indicated in the package inserts. Among the study population, patients who had received at least one oral medication through feeding tubes were assigned to tube feeding (TF) group, which is typically administered at the discretion of the doctor. The Beijing Hospital Ethics Committee approved this study prior to data collection. The study complies with the Declaration of Helsinki.

## Data Collection

Patient data was extracted from the Pharmacy Department database using predefined search terms, including "nasogastric tube (NGT) placement", "indwelling gastric tube", "nasogastric tube", "staying nasogastric tube", "nasogastric tube insertion", "jejunal tube", and "nasojejunal tube (NJT)". Subsequently, the medical records of patients were reviewed to gather relevant information, including age, gender, weight, department of care, type of feeding tubes, number of medications, dosage form, and related details. For analysis purposes, all patients who received medications through tube feeding were collectively classified into the TF group.

## Definition of Inappropriateness

There is currently no universally accepted criterion for the rationality of TF.[7,8] In this study, medications deemed "inappropriate" encompassed four distinct categories: (1) enteric-coated formulations via NGT; (2) modified-released formulations, or liquid-filled gelatin capsules administered via FT; (3) other medications that were not suitable for crushing;[7] (4) medications with altered bioavailability or physiochemical properties when administered via FT.[9] Other circumstances, such as wrong place of feeding tip distal end, tubes not flushed before and after administrations, were not investigated in our study.

## Statistical Analysis

Statistical analysis was performed with SPSS statistics 17.0. Continuous variables were presented as means ± standard deviations (SDs) for data following a normal distribution or as medians and interquartile ranges with non-normal distribution. Categorical variables were expressed as percentages. To assess variances between patients who received tube feeding and those who did not, T-tests or Chi-square tests were employed. A significance level of $P < 0.05$ was considered indicative of statistical significance.

# Results

## General Information on Patients With FT

Between January 2018 and December 2022, a total of 8,033 patients at the hospital received enteral nutrition via TF. After excluding pediatric patients and those who did not receive oral medication via TF, 7,243 patients were included in the study. The prevalence of tube feeding among hospitalized patients receiving oral medication administration was 6.26% during the study period. This cohort was designated as the TF group, and their demographic characteristics were compared with those of the entire study population, as summarized in Table 1. Compared to all hospitalized patients, the TF group exhibited a higher proportion of male patients (59.74% vs 48.91%), older age [(68.00±14.99) vs (59.75

**Table 1** Demographics of Patients With FT Compared to the All Study Population

| Characteristics | 2018 | | 2019 | | 2020 | | 2021 | | 2022 | | Total[a] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TP Group | All Patients | TP Group | All Patients | TP Group | All Patients | TP Group | All Patients | TP Group | All Patients | TP Group | All Inpatients | χ2/T Value | P-value |
| N | 1491 | 29.843 | 1655 | 30.820 | 1251 | 23.159 | 1667 | 29.565 | 1674 | 27.557 | 7243 | 115.772 | | |
| Male sex, N(%) | 870 (58.35) | 13.375 (44.82) | 1002 (60.54) | 13.837 (44.90) | 731 (58.43) | 10.376 (44.80) | 999 (59.93) | 13.866 (46.90) | 1006 (60.10) | 12.909 (46.84) | 4327 (59.74) | 56.630 (48.91) | 319.552 | <0.001 |
| Age, years | 68.29±15.00 | 59.85±16.68 | 67.48±15.42 | 59.94±16.56 | 68.94±15.38 | 60.25±16.31 | 68.24±15.06 | 61.17±15.52 | 69.78±14.62 | 61.46±15.52 | 68.00±14.99 | 59.75±16.38 | 41.788 | <0.001 |
| Weight[b], Kg | 65.37±12.95 | 67.76±12.58 | 65.90±13.12 | 68.07±12.69 | 65.41±13.45 | 67.86±12.63 | 65.66±13.80 | 67.86±12.76 | 65.16±13.21 | 67.79±12.75 | 65.75±13.32 | 67.82±12.72 | −12.229 | <0.001 |
| Bedridden (n, %) | 293 (19.65) | 1812 (6.07) | 296 (17.89) | 1712 (5.55) | 2409 (19.18) | 1306 (5.64) | 298 (17.88) | 1160 (3.92) | 322 (19.24) | 1242 (4.51) | 1308 (18.06) | 6223 (5.38) | 1908.053 | <0.001 |
| Hospitalization duration, days | 24.16±54.02 | 9.54±13.81 | 19.09±16.87 | 9.17±7.54 | 22.31±17.52 | 9.10±11.77 | 20.31±13.51 | 8.50±6.70 | 22.48±44.56 | 8.52±13.51 | 21.56±28.12 | 8.88±10.88 | 83.262 | <0.001 |
| Number of medications[c] | 51.41±19.59 | 22.85±15.15 | 48.95±19.70 | 23.93±15.26 | 50.62±19.11 | 22.61±15.88 | 50.10±19.20 | 22.23±12.49 | 50.10±20.40 | 22.59±14.89 | 51.21±19.37 | 23.35±15.04 | 150.119 | <0.001 |

**Notes**: TP: tube feeding. All patients referred to all hospitalized individuals who are aged 18 years or older and have at least one oral medication. a: Because some patients were readmitted from 2018 to 2022, the total number of patients was less than the sum of the number of patients in each year.b: Bedridden patients do not have weight data.c: Medications here refer to all drugs used during the patient's hospitalization, including oral medications, intravenous medications, topical medications, etc.

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±16.38)], lower weight [(65.75±13.32) vs (67.82±12.72)], increased rates of being bedridden (18.06% vs 5.38%), longer hospital stay [(21.56±28.12) vs (8.88±10.38)], and a greater number of prescribed medications types [(51.21±19.37) vs (23.35±15.04)], as detailed in Table 1. Notwithstanding these demographic differences, the data remained consistent from 2018 to 2022. Within the TF group, 6,535 patients received medications through NGT, while 708 patients were administered via NJT, as indicated in Table 2. On average, each patient received 8.92±6.78 types of oral medications. Finally, the top five hospital wards with the highest number of patients undergoing TF were the General Surgery Department, Emergency Department, Neurology Department, Respiratory Department, and Gastroenterology Department.

## Inappropriate Medication Administration in the TF Group

The investigation revealed that a substantial proportion (65.43%) of patients in the TF group experienced inappropriate medication administration. The rate of inappropriate medication administration via the NGT and NJT were 64.06% (4186/6535) and 78.11% (553/708), respectively. The total instances of inappropriate medication administration amounted to 10,164, resulting in an average occurrence rate of 1.40 occurrences per patient. Table 3 lists the specific medications administered inappropriately through FTs, including enteric-coated drugs, modified-release formulations, and non-crushable drugs.

Notably, aspirin enteric-coated tablets were the most frequently administered enteric-coated medication via nasal feeding, accounting for 15.38% of patients. Additionally, proton pump inhibitors (PPIs) emerged as the most commonly prescribed enteric-coated drugs, with inappropriate usage observed in 27.29% of all patients within the TF group. Other frequently prescribed enteric-coated drugs included diammonium glycyrrhizinate enteric-coated capsules, compound azintamide enteric-coated tablets, lumbrokinase enteric-coated tablets, and kininogenase enteric-coated tablets.

Inappropriate administration of modified-release formulations was also noted; potassium chloride sustained-release tablets, acetaminophen sustained-release tablets, nifedipine controlled release tablets, metoprolol succinate sustained-release tablets, and tamsulosin hydrochloride sustained release capsules were among the most commonly administered.

Finally, the study documented non-crushable formulations such as polyene phosphatidylcholine capsules, nimodipine tablets, glimepiride tablets, carbamazepine tablets, and dabigatran etexilate capsules that were inappropriately administered due to their physicochemical properties or dosage forms.

**Table 2** Summary of Basic Information on Tube Feeding Administration

| Item | Patients, n | Proportion of All Tube Feeding Patients, % |
|---|---|---|
| Type of FT | | |
| NGT | 6535 | 86.92 |
| NJT | 708 | 9.42 |
| Duration of feeding tube placement | | |
| Short term[a] | 3053 | 40.61 |
| Long term[b] | 4190 | 55.73 |
| Number of oral medications | | |
| 1–5 | 2684 | 35.70 |
| 6–10 | 2068 | 27.51 |
| 11–15 | 1192 | 15.86 |
| 16–20 | 681 | 9.06 |
| >21 | 618 | 8.22 |

**Notes**: a: patient was unable to eat orally after surgery and was given tube feeding for no more than 28 days.b: The duration of tube feeding was longer than 28 days. **Abbreviations**: FT, feeding tube; NGT, nasogastric tube; NJT, nasojejunal tube. Gastrostomy or jejunostomy tubes were excluded in our study.

**Table 3** Summary of Inappropriately Administered Medications via FT

| Dosage Form | Generic Name | Frequency (n) | | | Proportion of All Patients Receiving FT Dosing (n=7243), % |
|---|---|---|---|---|---|
| | | NGT Dosing | NJT Dosing | Total | |
| Enteric-coated drugs | | | | | |
| | Aspirin enteric-coated tablets | 1028 | 86 | 1114 | 15.38 |
| | Esomeprazole magnesium enteric-coated tablets[a] | 538 | 99 | 637 | 8.79 |
| | Pantoprazole enteric-coated tablets | 544 | 53 | 597 | 8.24 |
| | Rabeprazole sodium enteric-coated tablets | 470 | 52 | 522 | 7.21 |
| | Pancreatic enzyme enteric capsules | 187 | 36 | 223 | 3.08 |
| | Omeprazole enteric enteric-coated capsules | 160 | 61 | 221 | 3.05 |
| | Diammonium glycyrrhizinate enteric-coated capsules | 154 | 10 | 164 | 2.26 |
| | Compound azintamide enteric-coated tablets | 86 | 5 | 91 | 1.26 |
| | Lumbrokinase enteric-coated tablets | 25 | 2 | 27 | 0.37 |
| | Pancreatic kininogenase enteric-coated tablets | 23 | 0 | 23 | 0.32 |
| Modified-released drugs | | | | | |
| | Potassium chloride sustained-release tablets | 1317 | 128 | 1445 | 19.95 |
| | Paracetamol sustained-release tablets | 611 | 65 | 676 | 9.33 |
| | Nifedipine controlled-release tablets | 614 | 56 | 670 | 9.25 |
| | Metoprolol succinate sustained-release tablets | 373 | 39 | 412 | 5.69 |
| | Tamsulosin hydrochloride sustained-release capsules | 351 | 31 | 382 | 5.27 |
| | Isosorbide mononitrate sustained-release tablets | 325 | 28 | 353 | 4.87 |
| | Sodium valproate sustained-release tablets | 177 | 19 | 196 | 2.71 |
| | Trimetazidine dihydrochloride sustained-release tablets | 162 | 12 | 174 | 2.40 |
| | Cefaclor sustained-release tablets | 149 | 14 | 163 | 2.25 |
| | Theophylline sustained-release tablets | 107 | 6 | 113 | 1.56 |
| | Felodipine sustained-release tablets | 85 | 5 | 90 | 1.24 |
| | Oxycodone hydrochloride sustained-release tablets | 69 | 8 | 77 | 1.06 |
| | Doxazosin mesylate extended-release tablets | 60 | 12 | 72 | 0.99 |
| | Tramadol hydrochloride sustained-release tablets | 50 | 5 | 55 | 0.73 |
| | Ibuprofen sustained-release capsules | 38 | 5 | 43 | 0.59 |
| | Gliclazide sustained-release tablets | 34 | 4 | 38 | 0.52 |
| | Morphine sulfate sustained-release tablets | 28 | 2 | 30 | 0.41 |
| | Diltiazem hydrochloride sustained-release capsules | 21 | 3 | 24 | 0.33 |
| | Venlafaxine hydrochloride sustained-release capsules | 19 | 1 | 20 | 0.28 |
| | Mirabegron sustained-release tablets | 13 | 3 | 16 | 0.22 |
| | Allopurinol sustained-release capsules | 15 | 1 | 16 | 0.22 |
| | Mesalazine sustained-release capsules | 7 | 1 | 8 | 0.11 |
| | Tolterodine L-tartrate sustained-release tablets | 6 | 1 | 7 | 0.10 |
| | Carbidopa-levodopa sustained-release tablets | 5 | 1 | 6 | 0.08 |
| | Glipizide controlled-release tablets | 6 | 0 | 6 | 0.08 |
| | Metformin hydrochloride sustained-release tablets | 2 | 0 | 2 | 0.03 |
| Soft capsules | | | | | |
| | Calcitriol soft capsules | 266 | 30 | 296 | 4.09 |
| | Butylphthalide soft capsules | 118 | 6 | 124 | 1.71 |
| | Alfacalcidol soft capsules | 45 | 5 | 50 | 0.69 |
| | Sesame seed soft capsule | 6 | 1 | 7 | 0.10 |
| | Nintedanib esilate soft capsules | 5 | 0 | 5 | 0.07 |
| | Huoxiang Zhengqi soft capsule | 3 | 1 | 4 | 0.06 |
| | Sulodexide soft capsules | 1 | 0 | 1 | 0.01 |
| | Yindan Xinnaotong soft Capsule | 1 | 0 | 1 | 0.01 |

(*Continued*)

**Table 3** (Continued).

| Dosage Form | Generic Name | Frequency (n) | | | Proportion of All Patients Receiving FT Dosing (n=7243), % |
|---|---|---|---|---|---|
| | | NGT Dosing | NJT Dosing | Total | |
| Other non-crushable drugs | | | | | |
| | Compound digestive enzyme capsules | 146 | 19 | 165 | 2.28 |
| | Polyene phosphatidylcholine capsules | 151 | 12 | 163 | 2.25 |
| | Nimodipine tablets | 84 | 13 | 97 | 1.34 |
| | Glimepiride tablets | 63 | 5 | 68 | 0.94 |
| | Carbamazepine tablets | 32 | 5 | 37 | 0.51 |
| | Dabigatran etexilate capsules | 30 | 1 | 31 | 0.43 |
| | Cefuroxime axetil tablets | 29 | 2 | 31 | 0.43 |
| | Amiodarone tablets | 25 | 2 | 27 | 0.37 |
| | Alendronate sodium tablets | 4 | 0 | 4 | 0.06 |
| | Ciclosporin soft capsules | 3 | 0 | 3 | 0.04 |
| Drugs not suitable for jejunal tube administration[b] | | | | | |
| | Itraconazole capsules | NA | 147 | 147 | 2.03 |
| | Sucralfate suspension | NA | 71 | 71 | 0.98 |
| | Hydrotalcite chewable tablets | NA | 62 | 62 | 0.86 |
| | Sodium bicarbonate tablets | NA | 29 | 29 | 0.40 |
| | Vitamin B12 tablets | NA | 28 | 28 | 0.39 |
| Total | | 8871 | 1293 | 10.164 | 140.30 |

**Notes**: a: In our hospital, there are two types of proton pump inhibitors (PPIs) that can be dispersed in water: Losec® (Omeprazole magnesium enteric-coated tablets) and Nexium® (Esomeprazole magnesium enteric-coated tablets) manufactured by AstraZeneca AB.Other PPIs were judged as unreasonable utilization.b: These drugs can be administered via NGT. Therefore, only the NJT dosing was counted.
**Abbreviations**: FT, feeding tube; NGT, nasogastric tube; NJT, nasojejunal tube.

## Medications That Alter Bioavailability in the Presence of Enteral Nutrition

Certain medications have been found to exhibit reduced bioavailability when co-administered with enteral nutrition formulas. This reduction is primarily attributed to interactions between these medications and nutrients present in the enteral formula. Table 4 provides a concise overview of specific medications affected by this interaction. It is noteworthy that, as per established pharmacy knowledge, these medications were not indicated for use in combination with enteral nutrition. Furthermore, it should be emphasized that since the specific type of enteral nutrition was not examined in this analysis, and these medications were not classified as inappropriate.

**Table 4** Medications With Altered Bioavailability in Combination With Enteral Nutrition

| Medications | Frequency (n) | Proportion of All Patients Receiving FT Dosing (n=7243), % |
|---|---|---|
| Furosemide tablets | 4777 | 65.95 |
| Levodopa tablets | 961 | 13.27 |
| Moxifloxacin hydrochloride tablets | 754 | 10.41 |
| Levofloxacin tablets | 630 | 8.70 |
| Levothyroxine sodium tablets | 229 | 3.16 |
| Warfarin sodium tablets | 52 | 0.72 |
| Aminophyline tablets | 32 | 0.44 |
| Rifampin tablets | 22 | 0.30 |
| Phenytoin tablets | 4 | 0.06 |

**Abbreviation**: FT, feeding tube.

## Discussion

It has long been recognized that enteral feeding plays a vital role in preventing malnutrition.[10] For the convenience of both the patient and nursing staff, oral medications are frequently administered via the feeding tube for those requiring enteral feeding. However, the administration of medications to patients receiving specialized nutritional support can arise numerous complications.[11] In our research, 6.26% of hospitalized patients were receiving tube feeding, and this rate exhibit age-related increase. Patients receiving tube feeding also demonstrated a higher percentage of male individuals, advanced age, lower body weight, increased rates of being bedridden, prolonged hospital stays, and a greater variety of prescribed medications.

In clinical practice, it is common to administer medications alongside nutrients through feeding tubes, particularly in critically ill patients. Two primary methods are employed to prepare solid drug formulations for feeding tube administration: dispersing and crushing. The dispersing method is utilized when a drug disperses completely within 2 minutes.[2] To ensure safe and effective administration, the responsibility is shared among physicians, pharmacists, and nurses, although in practice, nurses often perform this task. The practice of grinding medications, referred to as "ground administration", is frequently adopted due to constraints related to drug knowledge and time limitations.[12] A number of medication errors have been linked to the administration phase, including the crushing of non-crushable dosage forms and inaccuracies in the drug delivery technique, such as failure to flush the tube before, between, and after administration.[13] Inappropriate administration via feeding tubes can lead to a range of consequences, including tube obstruction, aspiration pneumonia, reduced drug effectiveness, diarrhea, adverse drug reactions, and, in extreme cases, mortality.[14] In critically ill patients, medication errors related to crushing enteric-coated and modified-release drugs have notably increased the incidence of total tube obstruction.[15] These events not only negatively impact patient outcomes but also elevate medical resource utilization and the associated costs within the healthcare system.

In our study, we evaluated various dosage forms. Regular sugar-coated or film-coated tablets are typically amenable to crushing.[7,8] However, many oral medications have not been assessed for compatibility with feeding tube administration, which might result in alterations to their bioavailability.[16] Enteric-coated beads, for instance, are pH-sensitive and can agglomerate when mixed with water, potentially leading to gastric mucosa irritation and premature drug degradation if exposed to stomach acid. Crushing modified-release dosage forms disrupts the specialized coating, resulting in unpredictable blood concentrations and potential toxicity.[17] Feeding tube administration also poses challenges with liquid-filled soft capsules. Ensuring the complete extraction of the full dose from the gelatin shell can be problematic, and the viscous nature of the liquid may cause adherence to the tube wall, potentially leading to obstruction.[8] Moreover, certain dosage forms, such as sublingual tablets, drugs sensitive to humidity or light, and effervescent tablets are not suitable for grinding. Particular attention must be paid to the administration of compound digestive enzymes through feeding tubes, as it can give rise to issues like tube blockages and a loss of enzyme efficacy.[18] An investigation revealed that serum concentrations of amiodarone were significantly lower, sometimes even undetectable, when administered via feeding tube compared to oral dosing.[19]

Recent studies have revealed a significant disparity in the prevalence of inappropriate medication use. Gorzoni et al conducted an analysis on 57 patients who were receiving medications through feeding tubes (FT). Their findings indicated that approximately 35.4% of these medications were deemed inappropriate, with captopril, phenytoin, ranitidine, omeprazole, and B complex being the most frequently misused.[20] Idzinga et al focused on medication errors related to feeding tubes in patients with intellectual disabilities. They found that the preparation errors occurred in 64.5% (158/245) of patients before any intervention was implemented.[13] In another study conducted by Sohrevardi et al in the Intensive Care Unit (ICU), medication errors were identified in 76.6% (72/128) of the patients.[21] Despite the severity of the issue, clinical studies investigating the inappropriate administration of medication through feeding tubes remain relatively scarce.

Several factors contribute to this short fall. One reason is that many drug instructions fail to specify whether they should be administered via a feeding tube, which poses challenges for healthcare providers in determining the appropriateness of enteral administration. Moreover, nurses, who are often responsible for administering medications via feeding tubes, may exhibit lower awareness of the rational use of such medications compared to pharmacists.[12] Lastly, the inappropriate use of medications via feeding tubes can result from multiple factors, making it challenging to identify specific causes and solutions. Addressing this pressing issue requires concerted efforts to raise awareness, establish interdisciplinary practice guidelines, and invest in training programs.

In our investigation, we discovered that patients in our hospital received an average of 51.21±19.37 types of medications, of which 8.92±6.78 were oral medications, which is significantly higher than those reported previous studies. A study investigating medication errors via FTs in ICU reported an average of 13.84 types of medications, with 5.84 types of oral medications.[21] Another observational study in Belgium enrolled 156 residents, who received an average of 6.60 types of medications. Among these residents, 1% used one chronic drug, 32% used 2–5 chronic drugs, 52% used 6–9 drugs, and 14% used more than 9 drugs.[22] Polypharmacy increases the risk of medical error. When multiple medications are necessary, they should be administered separately and flushed with water each time.[23]

Our research also found that inappropriate use of PPIs accounted for 26.19% of all patients administered via NGT. In our hospital, only two types of PPIs, Losec® and Nexium®, could be dispersed in water due to their delayed-release, base-labile granules. Other PPIs should not be administered via FT, including pantoprazole, rabeprazole, and lansoprazole, as well as omeprazole and esomeprazole from different manufacturers.[24] PPIs should be dissolved in a fluid with an alkaline pH to avoid adverse effects and should not be crushed.[25] A nationwide survey in the United States highlighted that 39.9% of the problematic medications reported by nurses were PPIs. The study also showed that esomeprazole was the preferred PPI for patients requiring NGT administration, owing to its higher complete delivery rate, while the average loss rate for lansoprazole and omeprazole were 33% and 39%, respectively.[26] Another ICU-based study identified pantoprazole as the most frequently prescribed PPI, with a high incidence of incorrect dose preparation, reaching up to 34.04%.[21]

In general, tube obstruction not only hinders drug absorption but can also lead to delays in other administrations and, in some cases, necessitate tube replacement. For example, drugs like furosemide, fluoroquinolones (such as ciprofloxacin, levofloxacin, and moxifloxacin), warfarin, phenytoin, and levothyroxine have all demonstrated reduced bioavailability when co-administered with nutrition solutions.[27–31]It is also important to note that many medications have not been tested for oral absorption and bioavailability when administered through a feeding tube, and they may exhibit physico-chemical incompatibilities with the materials used in the tube.[32] In our research, we identified medications that interact with enteral nutrition. It's important to recognize that since this study did not explore the specific method of tube feeding nutrition; therefore, these medications were not classified as inappropriate medications. Consequently, it is plausible that the actual rate of inappropriate medication use in this context is higher than what was revealed in our research.

The limited literature on administering most drugs via FT underscores the need for further studies to guide practitioners in administering drugs via FT. A systematic evaluation revealed that only 37.93% of oral chemotherapy drugs included information on enteral tube administration, with only 4.60% featuring NGT administration instructions in their prescribing information.[33] Consequently, it is crucial to carefully analyze the risks and benefits associated with medication administration through an FT, as well as considering appropriate alternative dosage forms.[34] Pharmacists play a pivotal role in offering guidance on medication administration, but often rely on their broad pharmaceutical knowledge due to limited available guidance. They should consider discontinuing or switching to another therapeutic drug with a suitable dosage form that can be safely administered through FT. Lastly, to ensure patient comfort and safety while maintaining effective medication administration and flushing, the use of the smallest, softest tubes feasible is advisable.

This study underscores the need for developing educational programs aimed at enhancing awareness of current guidelines among nurses and physicians. Intervention programs involving pharmacists have demonstrated their effectiveness in mitigating medication errors and improving staff proficiency in medication administration via FT, both in institutions for individuals with intellectual disabilities,[12] and in hospital settings.[35] Therefore, it is imperative for pharmacists to actively engage in addressing these challenges and collaborate with healthcare professionals to ensure that patients receive medication via FT in an effective and safe manner.

However, several limitations must be considered when interpreting the results of this study. Firstly, inappropriate administration via FT including two categories: medications unsuitable for feeding tube administration and improper medication administration techniques. It is essential to recognize that the appropriateness of TF is influenced by various factors, but this study specifically focused on the analysis of inappropriate medications. Secondly, the investigation adopted a retrospective case-control design, which makes it susceptible to selection bias. Lastly, although the study was conducted in a substantial hospital setting, the findings may not be applicable to all patient populations.

## Conclusion

The objective of this study was to evaluate the appropriateness of medication administration through the FT route at a tertiary care hospital. Our results indicate a significant issue with inappropriate medication administration via FT. Ensuring the accurate administration of orally prescribed medications to patients with FTs is a complex task that requires immediate attention. Comprehensive foundational knowledge about medication properties and essential considerations for FT administration should be imparted to healthcare practitioners. Nurses should consult with clinical pharmacists to ensure patient safety and wellbeing of tube feeding medication.

## Data Sharing Statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of Beijing Hospital (Permit Number: 2023BJYYEC-185-01).

There is no identifying information of human participants in the manuscript. Our research was approved to exempt from patient informed consent by Ethics Committee of Beijing Hospital (Permit Number: 2023BJYYEC-185-01).

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## Disclosure

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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