Original Article

Risk factors contributing to morbidity associated with feeding tubes placed for esophageal cancer patients undergoing esophagectomy: a single-center retrospective study

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Background: Perioperative nutritional optimization of patients undergoing esophagectomy for cancer is important as this population is prone to malnutrition associated with poor outcomes. Nutritional supplementation has been achieved via enteral nutrition through percutaneous feeding tubes such as gastrostomy (G-tubes) and surgical jejunostomy tubes (J-tubes). While they are often routinely placed for patients undergoing esophagectomy, these are associated with adverse events including infections, dislodgement, increased healthcare visits, among others. The morbidity associated with feeding tubes has not been well characterized. We aim to determine factors associated with adverse outcomes after feeding tube placement to guide appropriate use of feeding tubes in esophageal carcinoma patients.

Methods: Patients who underwent esophagectomy for carcinoma and had at least one feeding tube placed from November, 2017 to October, 2021 at a single institution were retrospectively reviewed. Subgroup analyses were performed testing for relevant characteristics. Univariate and multivariate logistic regression analyses were conducted evaluating outcomes of interest. The primary outcome was the overall rate of tube-related complications.

Results: A total of 144 patients were included with 212 feeding tubes placed (75 G-tubes; 137 J-tubes). The rate of any adverse event related to feeding tubes was 39%. Of these, 11% were wound infections, 16% required procedural intervention, 11% visited the emergency department (ED), and 2.5% required admission due to feeding tube-related complications. Factors independently associated with adverse events included smoking history [odds ratio (OR), 2.80; 95% confidence interval (CI): 1.34–6.23], being female (OR, 2.98; 95% CI: 1.36–6.72), induction treatment (OR, 2.65; 95% CI: 1.14–6.55), and J-tubes (OR, 2.07; 95% CI: 1.09–4.03). Laparoscopically placed J-tubes were associated with increased unplanned admissions compared to those placed via laparotomy (9.4% *vs.* 0%, P=0.01). Though not statistically significant, there was a trend toward more complications in those who were high risk for malnutrition [body mass index (BMI) <18 kg/m^2, weight loss >10%] and comorbid (Charlson Comorbidity Index 5–6).

Conclusions: There is significant morbidity related to feeding tubes. The risk profile of these tubes for individual patients should be carefully weighed against the nutritional benefits prior to placement. Patients should be carefully counselled on the possible adverse events and care requirements.

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Introduction

Background

Esophageal cancer is the malignancy associated with the highest risk of malnutrition with 80% of all affected patients reporting over 10–15% unintentional weight loss prior to their diagnosis (1,2). In cancer patients, malnutrition is associated with adverse perioperative outcomes and diminished long-term survival (3-5). As a result, multiple strategies to counter malnutrition in cancer patients have been employed. Perioperative nutritional optimization is now achieved through various enteral (oral hydration, oral supplementation, nasogastric, gastric, or jejunal feeding tube nutrition) and parental routes (total parental nutritional or home IV hydration). The enteral route is preferable when possible as it is more physiologic and associated with less septic complications (6,7).

There is evidence that placement of feeding tubes in the perioperative period for esophageal cancer patients improves patient-related outcomes including overall survival rates, postoperative complications, and length of hospital stay (8-10). As such, many surgeons either routinely or selectively secure a feeding tube pre-operatively for induction treatment or at time of esophagectomy for post-operative nutrition.

Percutaneous gastrostomy tubes (G-tubes) are usually placed by interventional radiology (IR) prior to induction treatment and surgical jejunostomy tubes (J-tubes) are often placed at time of diagnostic laparoscopy prior to induction treatment, or during the esophagectomy for post-operative nutrition.

Although a common practice, these feeding tubes have been shown to be associated with significant morbidities for the patient including dislodgement, blockage, infection, bowel obstructions, and increased need for procedural interventions (11-13). Studies have indicated that a high burden of emergency department (ED) visits up to 39.3% following esophagectomies are related to feeding tube issues, and of these visits, up to 17% resulted in re-admissions to hospital for management (12,13). There have been concerns that pre-operative placement of G-tubes could compromise the gastric vasculature and interfere with the use of the stomach as a conduit (14). Surgical jejunostomy tubes have also led to serious complications requiring re-laparotomy in 0–2.9% of esophagectomy patients in one systematic review (15).

Given the morbidity, guidelines now recommend selective use of feeding tubes after esophagectomy and recent studies support its safety (16,17). In Low *et al.* enhanced recovery after surgery (ERAS) guidelines, patients are considered high risk for malnutrition if they have severe dysphagia (tolerating only fluids/puree), unintentional weight loss greater than 10%, serum albumin <30 g/L, or body mass index (BMI) less than 18 kg/m^2 (16). The recommendations are to consider enteral feeding supplementation in these high-risk patients, whereas the low- and moderate-risk patients should be considered for dietary advice and oral supplements. This same group of high-risk patients, however, are also at higher theoretical risk of wound and healing complications from these feeding

Highlight box

Key findings

- Feeding tubes placed in patients who undergo esophagectomy for carcinoma carry significant complication rates with them, particularly in more comorbid and malnourished populations who also stand to benefit the most from these feeding tubes.

What is known and what is new?

- Feeding tubes are routinely placed for enteral nutrition for esophageal cancer patients undergoing treatment, however, their specific complications, and the risks associated with poor outcomes are not well studied.
- We identify being female, jejunostomy tubes (J-tubes), smoking history, receiving induction treatment, and laparoscopic J-tube placement technique as risk factors for developing adverse events following feeding tube placement.

What is the implication, and what should change now?

- For patients at high risk of malnutrition, the placement of feeding tubes should be considered against the individualized risk of adverse events for the patient considering their comorbidities and other risk factors.

tubes due to their malnutrition. This has not yet been well studied and it is still unclear if the relative benefits of enteral feeding through feeding tubes outweigh the potentially increased risk of complications in this group. We present this article in accordance with the STROBE reporting checklist (available at https://jgo.amegroups.com/article/view/10.21037/jgo-23-891/rc).

Rationale and knowledge gap

The morbidity associated with percutaneous feeding tubes and risk factors resulting in adverse outcomes have not been well characterized in literature. There is currently no standardization or consensus regarding perioperative nutritional optimization and in whom their benefits would outweigh the potential morbidities.

Objective

Our primary objectives were to (I) determine the prevalence and type of adverse events following the placement of feeding tubes in esophageal carcinoma patients undergoing esophagectomy, and (II) determine the risk factors for developing these adverse events in order to guide appropriate selection of patients for the placement of feeding tubes and to direct patient counselling regarding their morbidity.

Methods

Study design

This is a retrospective cohort study. We retrospectively identified patients who underwent an esophagectomy for carcinoma and had at least one feeding tube (G- or J-tube) placed from November, 2017 to October, 2021 at a single institution at the London Health Sciences Centre (LHSC) in (London, ON, Canada). These patients were identified from an ongoing local quality improvement research project which tracks all Thoracic Surgery patients undergoing surgery at LHSC in a spreadsheet and encodes them by type of operation and disease. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional ethics board of Western Research Ethics Board (REB) (approval No. 119812) with associated ReDa Lawson Health Research Institute (approval No. 11690) which oversee and approve research conduct at LHSC.

Institution feeding tube pathway for esophageal cancer patients undergoing esophagectomy

At the center of study, esophageal cancer patients who are to undergo esophagectomy routinely receive feeding tube placement, typically a percutaneous IR placed G-tube, or laparoscopic jejunostomy tube at time of diagnostic laparoscopy prior to induction treatment. This was done to prevent hospitalization due to complications associated with induction treatment such as acute obstruction, dysphagia, and dehydration where a feeding tube could allow patients to receive nutrition and rehydration at home. In addition, they routinely receive a surgical jejunostomy tube at time of esophagectomy. This was placed routinely to mitigate malnutrition post-operatively in cases with complications such as anastomotic leaks where patients would not have adequate enteral nutrition otherwise. The nutrition management following feeding tube placement is managed by the dedicated Thoracic Surgery and London Regional Cancer Program (LRCP) dietitians on an individual basis tailored to the patient and their characteristics without a formal protocol. Post-operatively, typically patients are discharged home with their feeding tubes and at-home enteral nutrition titrated to their nutritional requirements. Feeding tubes most frequently are removed in post-operative clinic visits once the patients' oral intake is sufficient.

Protocol for feeding tube placement techniques

Individual surgeons and institutions will have various methods for placing feeding tubes. At LHSC and for this study, each feeding tube described was placed following these general protocols locally:

- ❖ IR-placed G-tube: the radiologist will place a nasogastric tube and distend the stomach with air. Then, under conscious sedation and local anesthetic as well as fluoroscopy, the intra-abdominal wall is punctured with a needle and the tract is secured and dilated in standard Seldinger fashion. This is followed by the placement of a multipurpose tube, the size of which is determined by the interventionalist at time of procedure. Two anchoring gastropexy sutures are secured between the stomach and the anterior abdominal wall which are removed after 7 days. G-tube feeds commence the following day.
- ❖ Laparoscopic feeding jejunostomy tube: a loop of jejunum typically 40–50 cm distal to the Ligament

of Treitz is selected and brought up to the anterior abdominal wall. A needle is used to puncture through the abdominal wall then the jejunum and a polyvinyl chloride (PVC) 14 Fr feeding tube is inserted through in standard Seldinger fashion. Jejunopexy in four quadrants is then completed in addition to an anti-torsion stitch just distal to the jejunostomy using a dissolvable suture laparoscopically. Outside 0-Prolene sutures are used to secure the tube to the feeding tube. J-tube feeds commence the following day.

❖ Open feeding jejunostomy tube: a loop of jejunum typically 40–50 cm distal to the Ligament of Treitz is selected and brought up to the anterior abdominal wall. A jejunostomy is created with cautery and a 14 Fr silastic foley catheter is inserted through the anterior abdominal wall into the jejunostomy running distally and it is Witzeled in using 3-0 Silk sutures and then jejunopexy is performed in four quadrants as well as two anti-torsion sutures proximal and distal along the jejunum. This is secured externally to the skin using a 0-Prolene suture. J-tube feeds commence the following day.

Data collection

For each patient, relevant data on basic patient demographics such as age, sex, comorbidities, weight, height, weight loss within the last 6 months, serum albumin, as well as cancer details, treatment plans, and feeding tube types were collected. Following this, outcome variables pertaining to adverse events associated with feeding tubes were collected including number of ED visits, re-admissions, and clinic visits directly related to feeding tube issues, as well as number of tube dislodgements, re-operations, procedures, surgical site infections, and deaths. The adverse events were then categorized according to the Clavien-Dindo classification for standardization for complications (18). Using consultation and pre-operative notes, a Charlson Comorbidity Index (CCI) score was calculated for each patient. Surgical site infections were defined by the description of findings concerning for a wound infection, such as erythema, purulence, and tenderness, in addition to an action of management, typically antibiotics or the removal of the feeding tube. Procedural re-interventions pertain to the need for a procedure by IR in order to replace a dislodged or malfunctioning tube. We collected all data up to the removal of the feeding tube or 3 months post-esophagectomy, whichever was sooner. Some patients post-operatively either were switched to symptom-management and comfort measure care, or had persistent dysphagia requiring the ongoing need for a feeding tube beyond the scope of the perioperative period that our study examined.

Bias

Our study contains potential for information bias particularly with regards to outcome data collection differences between patients with G-tube complications and J-tube complications. LHSC is a tertiary center for many patients from various surrounding regions, and patients who received G-tubes for nutrition through their induction treatment prior to their esophagectomy were more likely to present to LHSC for any complications with feeding tubes given that for many of them, their induction treatment was already at the LHSC cancer center. Patients who had received J-tubes at time of esophagectomy and were discharged home could have presented to various other regional hospitals for complications which could be outside of our electronic medical record (EMR) and therefore be missed in our retrospective data entry. To mitigate this bias, all post-operative clinic visit documents for each patient were screened in order to attempt to capture any reported visits not in our EMR. It is additionally the local practice for regional hospitals to ask patients to present to their surgeon after issues with their feeding tubes and it is likely that almost all feeding tube issues would have been captured in our data entry in one way or another, however, this bias still exists.

Sample size

Previous literature identified up to approximately 40% of complications with feeding tubes overall (12). Given we were interested in studying 8 outcome variables, assuming we needed at least 10 positive events per variable, we determined we required at least 200 feeding tubes as a sample size. After giving an extra margin and rounding to the nearest full study year, we studied 4 years of esophagectomy patients at LHSC which resulted in a total of 212 feeding tubes. The study period was also determined by significant changes in previous local feeding tube practices and EMR systems which precluded a study period spanning further back.

Statistical analysis

Subgroup analyses were performed testing for relevant characteristics. Univariate and multivariate logistic regression analyses were conducted evaluating outcomes of interest using RStudio™. The primary outcome was the overall rate of tube-related complications. Secondary outcomes included ED visits, re-admissions, clinic visits, procedural reinterventions, tube dislodgement, wound infections, and deaths. Our variables of interest used to build the multivariate model include the smoking status, type of tube, sex, induction therapy, BMI, diabetes, weight loss greater than 10%, serum albumin, and CCI. Wilcoxon rank sum test was used to analyze continuous data, Chi-Square test was used for proportions, and Fisher's exact test for categorical variables. Bidirectional stepwise regression with the lowest Akaike information criterion (AIC) was performed to select variables of interest to build our multivariate model, finding the model with the least number of variables. With regards to missing data, only one patient had missing weight and height information which precluded our ability to calculate BMI and therefore our ability analyze adverse outcomes as related to percentage of weight loss and BMI. We determined this data was missing completely at random and given it was a single patient, excluded them from the relevant analyses. All other patients had all relevant data clearly documented given these were all critical to their clinical care.

Results

Over the 4-year period, a total of 144 patients were included with the placement of 212 feeding tubes (75 G-tubes and 137 J-tubes) (*Table 1*). All patients examined were eligible for our study as the standard local practice at the time included placement of feeding tubes both for induction treatment and at time of esophagectomy for all esophageal carcinoma patients. All patients had documented follow-up and were included in our analyses. Only one patient had missing demographic data including weight and height. Patient outcomes were followed and recorded up to 3 months following placement of each feeding tube.

All G-tubes were placed by IR. Thirty-two (23%) of the J-tubes were placed laparoscopically either at time of diagnostic laparoscopy before induction therapy or at time of esophagectomy, and 105 (77%) of them were completed in an open fashion at time of esophagectomy. There were no open J-tubes placed before induction therapy. The mean age of patients included in this study was 67.9 years. There were significantly more men (83%) than women (17%) in the study. A significant portion of the population (75%) were current- or ex-smokers.

The rate of any adverse event related to feeding tubes was 39% (*Table 2*). Of these, 10% were wound infections, 17% required procedural re-interventions, 10% visited the ED for reasons directly related to the feeding tube, and 2.8% required admission due to feeding tube-related complications. There were no cases of gastric conduit compromise secondary to pre-operative G-tube placement. There was no mortality associated with these tubes.

Risk factors for feeding tube complications

Multiple patient-related, feeding tube, and treatment variables were examined for their impact on. individual and overall complication rates. Female patients had an increased complication-rate compared to male patients (57% *vs.* 35%, P=0.01) (Table S1). Specifically, women had more ED visits compared to men (22% *vs.* 8%, P=0.03) (Table S1).

Current or previous smoking history was a significant risk factor for overall complications when compared to non-smokers (44% *vs.* 23%, P=0.006) (*Figure 1*). Smoking significantly increased the risk of requiring an IR procedure re-intervention when compared to non-smokers (19% *vs.* 7.5%, P=0.04) (*Figure 1*). Patients with a higher CCI of 5–6 did not have statistically significant higher rates of complications when compared to those with CCI of 3–4 or 0–2 (58% *vs.* 41% *vs.* 34%, P=0.19) (*Figure 2*). Patients with diabetes did not have significantly higher rates of complications when compared to those without (22% *vs.* 78%, P=0.91) (Table S2).

When analyzing tube-specific characteristics between G- and J-tubes placed prior to induction treatment, we note a higher overall complication rate associated with J-tubes with a trend toward requiring more IR re-interventions (58% *vs.* 31%, P=0.01) (*Figure 3*). There was no difference in severity of the complications when comparing the Clavien-Dindo complication grades of these pre-induction G-tube and J-tube complications. The most common grade of complication was IIIA for complications requiring IR reintervention (43% for G-tubes, 53% for J-tubes) followed by grade I complications (39% G-tubes, 20% J-tubes) (P=0.49) (Table S3). There was no difference in complications between the laparoscopic and open J-tube insertion approach when placed prior to induction treatment (53% *vs.* 67%, P=0.68) (Table S4). When looking at all feeding tubes placed at any point during treatment, there were no differences in complication rates when comparing G- and J-tubes (31% *vs.* 43%, P=0.08) (Figure S1). When

Table 1 Patients' demographic data

Variables	Overall (n=212)	G-tube (n=75)	J-tube (n=137)	P value
Age (years)	67.9±10.1	67.9±9.7	68.0±10.4	0.96
Sex				0.68
Female	37 [17]	12 [16]	25 [18]	
Male	175 [83]	63 [84]	112 [82]	
BMI, kg/m^2	24.6±4.9	24.2±4.9	24.9±4.9	0.33
BMI <18 kg/m^2	15 [7.1]	7 [9.3]	8 [5.9]	0.35
Weight loss >10%	71 [33]	29 [39]	42 [31]	0.24
BMI <18 kg/m^2 and weight loss >10%	12 [5.7]	6 [8.0]	6 [4.4]	0.35
Diabetes	46 [22]	14 [19]	32 [23]	0.43
Insulin-dependent diabetes	5 [11]	1 [7.1]	4 [12]	>0.99
CCI				0.67
0–2	106 [50]	40 [53]	66 [48]	
3–4	94 [44]	32 [43]	62 [45]	
5–6	12 [5.7]	3 [4.0]	9 [6.6]	
Smoking history				0.97
Current	59 [28]	21 [28]	38 [28]	
Ex-smoker	100 [47]	36 [48]	64 [47]	
Never	53 [25]	18 [24]	35 [26]	
Any induction therapy (chemoradiation)	174 [82]	72 [96]	102 [74]	<0.001
Serum albumin, g/L	37.8±5.8	39.0±4.2	37.2±6.4	0.04
Serum albumin <30 g/L	22 [10]	2 [2.7]	20 [15]	0.005
Type of esophagectomy				0.15
Ivor-Lewis	56 [26]	14 [19]	42 [31]	
McKeown	10 [4.7]	4 [17]	6 [4.4]	
Transhiatal	146 [69]	57 [76]	89 [65]	
Clavien-Dindo complication grade				>0.99
I	31 [38]	9 [38]	22 [37]	
II	16 [20]	4 [17]	12 [20]	
IIIA	34 [41]	10 [42]	24 [41]	
IIIB	1 [1.2]	0	1 [1.7]	
IV	0	0	0	
V	0	0	0	

Data is presented as mean ± SD or number [percentage]. SD, standard deviation; BMI, body mass index; CCI, Charlson Comorbidity Index.

Table 2 Feeding-tube complications rates

Complication	Number of complications [%]
Overall	82 [39]
Need for procedural re-intervention	35 [17]
Wound infections	22 [10]
Visit to emergency department	22 [10]
Unplanned re-admissions	6 [2.8]
Mortality	0

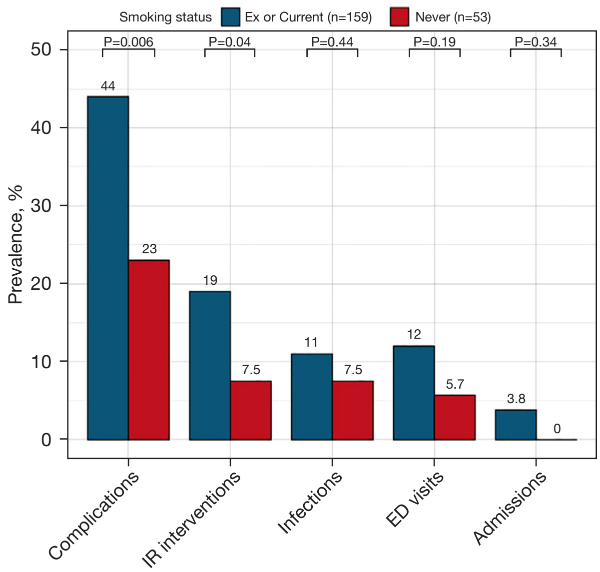

Figure 1 Prevalence of feeding-tube specific complications of current- or ex-smokers as compared to never smokers. Differences in prevalence of complication rates between current- or ex-smokers compared to never smokers in overall complications, IR interventions, wound infections, ED visits, and unplanned re-admission rates. IR, interventional radiology; ED, emergency department.

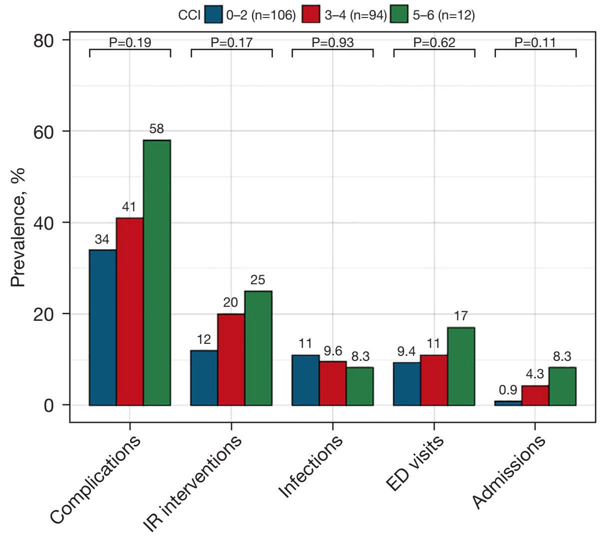

Figure 2 Prevalence of feeding-tube specific complications between patients with varying medical comorbidities. Differences in prevalence of complication rates amongst patients with a CCI of 0–2, 3–4, and 5–6 in overall complications, IR interventions, wound infections, ED visits, and unplanned re-admission rates. IR, interventional radiology; ED, emergency department; CCI, Charlson Comorbidity Index.

looking at all J-tubes, those placed laparoscopically resulted in more unplanned admissions compared to those via laparotomy (9.4% *vs.* 0%, P=0.01) and trended toward increased IR interventions (28% *vs.* 15%, P=0.10) (Table S5). There was no significant difference for feeding tubes placed before induction treatment versus at time of the esophagectomy (38% *vs.* 40%, P=0.76) (Table S6).

BMI less than 18 kg/m^2, weight loss greater than 10% in the last 6 months, and serum albumin <30 g/L were additionally specifically examined given that these patients are categorized as "High Risk" for malnutrition based on ERAS esophagectomy guidelines and therefore to be considered for perioperative enteral nutritional support (16). None of variables of BMI less than 18 kg/m^2 (47% *vs.* 38%, P=0.49) (*Table 3*), weight loss greater than 10% (48% *vs.* 34%, P=0.051) (*Table 4*), or serum albumin <30 g/L (39% *vs.* 32%, P=0.51) individually showed statistical differences in complications (*Table 5*). When looking at those who met criteria for all three of those high-risk malnutrition risk factors there was only patient who fit all and there was no statistical difference when compared to those who were not likely due to low incidence of the outcome (100% *vs.* 38%, P=0.38) (*Table 6*).

Out of 144 total patients in the study, 123 received induction therapy and 21 had upfront surgery. Of the 123 patients which underwent induction therapy, 119 underwent chemoradiation and only 4 underwent chemotherapy alone. When looking at treatment-specific outcomes, those who underwent induction treatment did not have increased overall complications when compared to those who did not undergo induction therapy (40% *vs.* 32%, P=0.32) (*Table 7*).

Female sex in addition to any smoking history were risk factors for overall complications when performing

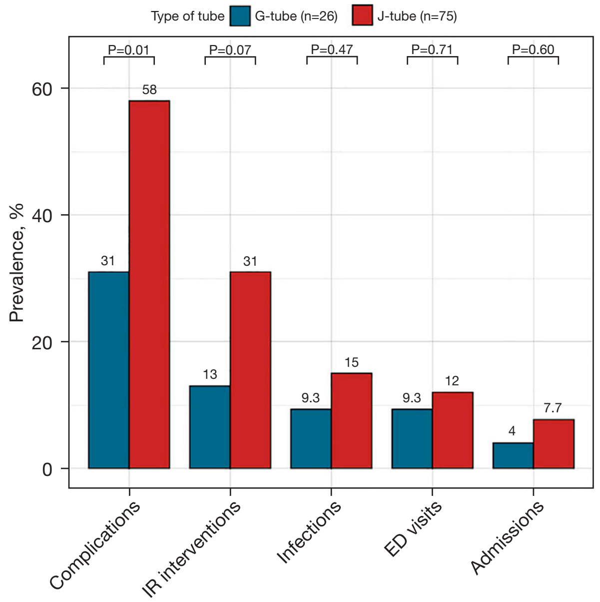

Figure 3 Prevalence of feeding-tube specific complications when comparing G- and J-tubes placed before esophagectomy. Differences in prevalence of complication rates between patients who received a G-tube compared to a J-tube prior to their esophagectomy in overall complications, IR interventions, wound infections, ED visits, and unplanned re-admission rates. IR, interventional radiology; ED, emergency department.

univariate analyses (*Table 8*). In our multivariate analyses for overall complications, J-tubes, female sex, any history of smoking, and BMI ≥30 kg/m^2, and any induction treatment were significant adverse risk factors. Univariate analysis of specific complications including wound infections, unplanned re-admissions, and IR re-interventions did not elucidate any significant risk factors.

Discussion

Feeding tube placement perioperatively for esophageal cancer patients undergoing esophagectomy is a common practice. However, these tubes can be associated with a multitude of adverse events and not all patients will require or benefit from their use during their treatment (11-13,15). Additionally, the morbidity associated with these tubes and the risk factors for an adverse outcome are not well described in literature. As such there is still currently no wide consensus about their use in this population. While it is understood that patients who would most likely benefit from these tubes are those who are at high risk of malnutrition, it is not clear which patients pose at high risk of developing adverse events associated with them (16).

In our study, we identify a high number of adverse events

Table 3 Feeding tube complications related to BMI

Variables	Overall (n=211*)	BMI <18 kg/m^2 (n=15)	BMI ≥18 kg/m^2 (n=196)	P value
Complications, n [%]	81 [38]	7 [47]	74 [38]	0.49
IR intervention, n [%]	34 [16]	3 [20]	31 [16]	0.71
Wound infection, n [%]	21 [10]	1 [6.7]	20 [10]	>0.99
Visits to the ED, n [%]	21 [10]	1 [6.7]	20 [10]	>0.99
Unplanned admissions, n [%]	6 [2.8]	1 [6.7]	5 [2.6]	0.36

*, one patient did not have height recorded and therefore BMI could not be calculated. That patient was excluded from analyses pertaining to BMI calculations. IR, interventional radiology; ED, emergency department; BMI, body mass index.

Table 4 Feeding tube complications related to weight loss

Variables	Overall (n=212)	<10% (n=141)	≥10% (n=71)	P value
Complications, n [%]	82 [39]	48 [34]	34 [48]	0.051
IR intervention, n [%]	35 [17]	20 [14]	15 [21]	0.20
Wound infection, n [%]	22 [10]	15 [11]	7 [9.9]	0.86
Visits to the ED, n [%]	22 [10]	13 [9.2]	9 [13]	0.44
Unplanned admissions, n [%]	6 [2.8]	4 [2.8]	2 [2.8]	>0.99

IR, interventional radiology; ED, emergency department.

Table 5 Feeding tube complications related to serum albumin <30 g/L

Variables	Overall (n=204*)	Albumin <30 g/L (n=182)	Albumin ≥30 g/L (n=22)	P value
Complications, n [%]	78 [38]	71 [39]	7 [32]	0.51
IR intervention, n [%]	33 [16]	27 [15]	6 [27]	0.14
Wound infection, n [%]	22 [11]	19 [10]	3 [14]	0.71
Visits to the ED, n [%]	20 [9.8]	18 [9.9]	2 [9.1]	>0.99
Unplanned admissions, n [%]	5 [2.5]	3 [1.6]	2 [9.1]	0.09

*, eight patients did not have an albumin recorded immediately following feeding tube placement and therefore were excluded from analysis. IR, interventional radiology; ED, emergency department; BMI, body mass index.

Table 6 Feeding tube complications in patients with BMI <18 kg/m^2, weight loss >10%, and albumin <30 g/L

Variables	Overall (n=203)*	No (n=202)	Yes (n=1)	P value
Complications, n [%]	77 [38]	76 [38]	1 [100]	0.38
IR intervention, n [%]	32 [16]	31 [15]	1 [100]	0.16
Wound infection, n [%]	21 [10]	20 [9.9]	1 [100]	0.10
Visits to the ED, n [%]	19 [9.4]	19 [9.4]	0	>0.99
Unplanned admissions, n [%]	5 [2.5]	5 [2.5]	0	>0.99

*, one patient did not have height recorded and therefore BMI could not be calculated and eight patients did not have an albumin recorded immediately following feeding tube placement and therefore these patients were all excluded from analysis. IR, interventional radiology; ED, emergency department.

Table 7 Feeding tube complications related to use of induction therapy

Variables	Overall (n=212)	No induction therapy (n=38)	Induction therapy (n=174)	P value
Age (years)	67.9±10.1	72.0±11.7	67.0±9.6	0.01
Complications	82 [39]	12 [32]	70 [40]	0.32
IR interventions	35 [17]	7 [18]	28 [16]	0.73
Wound infection	22 [10]	3 [7.9]	19 [11]	0.77
Visits to the ED	22 [10]	2 [5.3]	20 [11]	0.38
Unplanned admissions	6 [2.8]	1 [2.6]	5 [2.9]	>0.99

Data is presented as mean ± SD or number [percentage]. SD, standard deviation; IR, interventional radiology; ED, emergency department.

up to 39%, including both minor and major, associated with feeding tubes. There were no mortalities related to feeding tube morbidity during this period. Although there is a wide variation of reported complications and their frequencies, our findings are generally comparable to previous literature (12,13,15,19). While most morbidities were minor Grade I to IIIA Clavien-Dindo classification complications such as wound infections or tube dislodgement requiring an outpatient intervention, for patients, these minor adverse events including repeated ED and clinic visits can represent significant challenges given that these occur in the perioperative and often immediate postoperative period during recovery. Future studies examining patient-related opinions and quality of life in the post-operative period may elucidate the true patient burden of feeding tubes. Additionally, these adverse events represent large challenges for the already-burdened healthcare system with a significant amount of excess clinic visits, ED visits, and re-

Table 8 Univariate and multivariate analyses of overall tube-related complications

Variables	N	Univariate			Multivariate		
		OR	95% CI	P value	OR	95% CI	P value
J-tube	211	1.68	0.93–3.09	0.09	2.07	1.09–4.03	0.03
Female	211	2.34	1.13–4.89	0.02	2.98	1.36–6.72	0.007
Age ≥70 years	211	1.28	0.73–2.25	0.38			
Diabetic	211	1.04	0.53–2.02	0.91			
Current- or ex-smoker	211	2.65	1.33–5.62	0.008	2.80	1.34–6.23	0.008
BMI ≥30 kg/m^2	211	0.46	0.18–1.09	0.10	0.36	0.13–0.93	0.04
BMI <18 kg/m^2	211	1.44	0.49–4.18	0.50			
Albumin <30 g/L	203*	0.74	0.27–1.85	0.53			
Any induction treatment	211	1.59	0.75–3.55	0.24	2.65	1.14–6.55	0.03
Weight loss >10%	211	1.73	0.96–3.11	0.07			
BMI <18 kg/m^2 and weight loss >10%	211	1.65	0.50–5.46	0.40			
BMI <18 kg/m^2 and weight loss >10% and albumin <30 g/L	203	N/A	N/A	0.99			
CCI	211						
0–2		–	–				
3–4		1.34	0.75–2.40	0.32			
5–6		2.72	0.81–9.77	0.11			

*, eight patients did not have post-feeding tube placement albumins documented and therefore excluded from our analysis. OR, odds ratio; CI, confidence interval; BMI, body mass index; CCI, Charlson Comorbidity Index.

admission rates to hospital.

Our study further identified being female, J-tubes, smoking history, induction neoadjuvant chemoradiation, and laparoscopic J-tube placement technique as risk factors for developing adverse events. It is not surprising that comorbid patients and patients with wound-healing associated risk factors such as smoking had increased complications following feeding tube placement (20). In these populations, careful discussion should be had regarding the decision to place these feeding tubes and their associated potential increased risk.

We identified that J-tubes had increased complications when compared to G-tubes when looking at those feeding tubes placed prior to induction treatment as well as on our multivariate analysis looking across all feeding tubes. While they had increased frequency of complications, the severity of complications appeared to be similar between the two groups. Given that most of the J-tubes placed pre-esophagectomy were done through laparoscopic technique, we examined the difference in outcomes between laparoscopic and open techniques prior to induction treatment to see if the laparoscopic approach could account for the increase in morbidity, however, there was no statistical difference in complications between the two approaches before esophagectomy (53% *vs.* 67%, P=0.68) (Table S4). We do note that laparoscopically placed J-tubes had higher re-admission rates compared to J-tubes placed via laparotomy when considering all J-tubes together, both those placed before and at time of esophagectomy. Some of this observed effect is likely due to the fact that laparoscopically-placed J-tubes are often completed at time of diagnostic laparoscopy and patients are typically discharged the following day with outpatient resources for management of starting feeds and tube care with limited inpatient education on these topics. These patients have increased risk of needing re-admission for tube and dressing instructions, feeding tolerance and schedule, and inability to troubleshoot immediately on their own after their quick discharge.

Patients who had an open J-tube placed were all at time of esophagectomy and therefore typically stayed as inpatients for several days for recovery with more opportunity for education, allied health assessments, and starting feeds in a monitored setting. It remains an ongoing area of interest if the technique of placing J-tubes laparoscopically itself could lead to increased adverse effects.

Patients who underwent induction therapy with neoadjuvant chemoradiation were seen on the multivariate analysis model to have increased risk of complications associated with their feeding tubes. Radiation therapy in particular can be associated with impaired wound healing and may explain this effect (21). An analysis which would provide insight into if these are effects secondary to radiation would be to study our patients who underwent induction chemotherapy alone *vs.* chemoradiation, however, unfortunately there were only four patients who underwent chemotherapy alone and therefore not enough incidences to perform statistical analysis and draw conclusions from. This finding, however, suggests that the placement of feeding tubes in patients undergoing neoadjuvant treatment could in theory result in delays to definitive surgical therapy, particularly if patients develop wound infections requiring antibiotic treatment or are re-admitted for tube-related complications requiring reinterventions. This is an adverse outcome which may impact their cancer care and outcomes which would need to be discussed with patients requiring induction treatment prior to the placement of their feeding tubes.

Given the ERAS guidelines to consider a feeding tube for nutritional supplementation for high-risk malnutrition patients, we examined the adverse outcomes of those patients with BMI less than 18 kg/m^2, weight loss greater than 10%, serum albumin less than 30 g/L, and patients who had all three. The ERAS guidelines additionally considered those with severe dysphagia being able to tolerate puree and fluids only also within high risk, however, we did not have enough available data in our data set to analyze this characteristic (16). This data is novel and intriguing as our initial hypothesis was that the patients who are high-risk for malnutrition would concurrently be high-risk for wound- and healing-related tube complications. If this were the case, then those who would benefit the most from these feeding tubes would also be the ones who would expect the most complications with them, and therefore the risk-benefit would need to be carefully discussed to favor one or the other. Our data suggest, however, no statistical difference between complication rates of both groups and may suggest that those who benefit the most from the feeding tubes nutritionally are only at average risk for tube-related complications. This would then favor the placement of feeding tubes for supplemental enteral feeding in these high-risk patients as it would come with greater relative benefit with no apparent significant increase in risk. There is, however, a trend towards significance for increased complications in those with greater than 10% weight loss (P=0.051). This finding may be a byproduct of our small sample size and further research with more patient data would help elucidate if this is a true effect. At minimum, our data suggests that those with both significant weight loss and BMI <18 kg/m^2 have an approximate 50% chance of having a tube-related complication and this should be discussed as such with patients. Similarly, those with higher CCI scores showed a trend toward increased overall complication rates with feeding tubes signifying again that those who may require the supplemental feeds from feeding tubes the most will also be those who will have the most complications from them.

Limitations

Our study should be viewed in the context of several limitations. In our study, we focused on and examined only the adverse events related to the placement of feeding tubes. We did not explore the possible benefits in the form of potential nutritional improvement and overall patient-related outcomes as they have been previously studied. Our data additionally does not capture the effect of feeding tubes on long-term outcomes beyond 3 months. We did not review the hospital length of stay in our study as we reviewed both G- and J-tubes concurrently and the former was typically completed as a day procedure and discharged home with outpatient follow-up. Given that all esophageal cancer patients undergoing esophagectomy received routine placement of feeding tubes at our center during this time-period, we were not able to do comparative analysis to a population in which no feeding tubes were placed for overall post-operative outcomes.

We additionally did not review all post-operative esophagectomy outcomes, such as anastomotic leaks, given the focus on delineating tube-specific patient and system-related outcomes. Future studies should examine the patient perspective in the perioperative period regarding feeding tubes, their care, and the burden of adverse outcomes related to them. Lastly, our locoregional health care system largely shares one EMR which allows us to easily track healthcare visits for patients who are not local. However, regardless, it is still possible that a subsegment of patients could have visited a regional hospital not in our system for a tube-related reason. Even if this were the case, however, these ED visits would have been documented in subsequent clinic visits or patients would have been asked to follow-up with their surgeon, and this would have all been reviewed and documented.

Conclusions

There is significant morbidity related to feeding tubes. Routine use of feeding tubes for esophageal cancer patients undergoing esophagectomy should be avoided. Instead, patients should be stratified pre-operatively by nutritional status and their individual risk for malnutrition should be identified. For those who are high risk, the placement of a feeding tube should be considered against the individualized risk of adverse events for the patient considering their comorbidities and other risk factors. The risk profile of feeding tubes for should then be carefully discussed with the patient and emphasis should be placed on counselling patients on care of the feeding tube including the need to monitor for complications as well as the likelihood of increased perioperative healthcare visits related to tube complications.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jgo.amegroups.com/article/view/10.21037/jgo-23-891/rc

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jgo.amegroups.com/article/view/10.21037/jgo-23-891/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any party of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional ethics board of Western Research Ethics Board (REB) (approval No. 119812) with associated ReDa Lawson Health Research Institute (approval No. 11690) which oversee and approve research conduct at LHSC.

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