Association of conduit dimensions with perioperative outcomes and long-term quality of life after esophagectomy for malignancy

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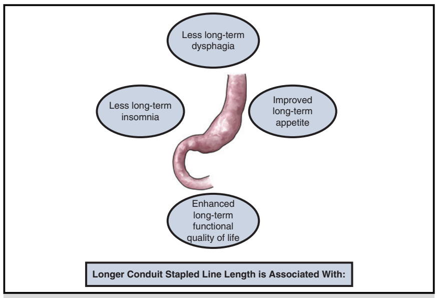
ABSTRACT

Objective: The impact of conduit dimensions and location of esophagogastric anastomosis on long-term quality of life after esophagectomy remains unexplored. We investigated the association of these parameters with surgical outcomes and patient-reported quality of life at least 18 months after esophagectomy.

Methods: We identified all patients who underwent esophagectomy for cancer from 2018 to 2020 in our institution. We reviewed each patient's initial postoperative computed tomography scan measuring the gastric conduit's greatest width (centimeters), linear staple line length (centimeters), and relative location of esophagogastric anastomosis (vertebra). Quality of life was ascertained using patient-reported outcome measures. Perioperative complications, length of stay, and mortality were collected. Multivariate regressions were performed.

Results: Our study revealed that a more proximal anastomosis was linked to an increased risk of pulmonary complications, a lower recurrence rate, and greater long-term insomnia. Increased maximum intrathoracic conduit width was significantly associated with trouble enjoying meals and reflux long term after esophagectomy. A longer conduit stapled line correlated with fewer issues related to insomnia, improved appetite, less dysphagia, and significantly enhanced "social," "role," and "physical" aspects of the patient's long-term quality of life.

Conclusions: The dimensions of the gastric conduit and the height of the anastomosis may be independently associated with outcomes and long-term quality of life after esophagectomy for cancer. (JTCVS Open 2024;17:306-19)



Longer conduit stapled line length is associated with improved long-term quality of life.

CENTRAL MESSAGE

Conduit dimensions and anastomotic height, as assessed through the first postoperative CT scan, may be associated with outcomes and long-term quality of life after esophagectomy for cancer.

PERSPECTIVE

We investigated whether the dimensional characteristics of the gastric conduit observed in the initial postoperative CT scan are associated with outcomes and the patient's quality of life at a minimum of 18 months after esophagectomy. Our findings suggest that conduit dimensions may be independently linked to perioperative outcomes and the long-term quality of life after esophagectomy for cancer.

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Abbreviations and Acronyms

- CT = computed tomography
- EORTC = European Organization for the Research and Treatment of Cancer
- HRQoL = health-related quality of life
- OES-18 = Esophagus 18 Module
- QLQ-30 = Quality of Life Questions Core 30 Module

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As survival from esophageal cancer improves, long-term quality of life is becoming an increased focus of survivorship for patients after esophagectomy.[1,2] Nevertheless, not all medical facilities conduct extended follow-up assessments of long-term quality of life of patients who undergo esophagectomy, and the optimal technique for esophagectomy is currently debated. The gastric conduit is the preferred replacement for the esophagus, and several reconstruction techniques have been devised to optimize its functional effectiveness and improve the quality of life.[3-5] To date, there are no quantitative data correlating conduit dimensions and long-term quality of life. Our study examined whether dimensional parameters from the initial postoperative computed tomography (CT) scan relate to perioperative outcomes and the patient's quality of life at least 18 months after esophagectomy. Understanding the association between the early dimensions of a newly reconstructed gastric conduit and the quality of life of long-term survivors may assist thoracic surgeons in operative planning.

MATERIAL AND METHODS

Study Design

The Massachusetts General Brigham Institutional Review Board (#2021P003188, approved on March 8, 2022) approved the study protocol, our analysis of the association between esophagectomy conduit dimensions and outcomes, and the publication of data. We identified all patients (age 18+ years) who underwent esophagectomy for malignancy between 2018 and 2020 at the Brigham and Women's Hospital. Implied informed consent for publication of study data was provided by the patients upon their voluntary completion of the survey. Patients who underwent transhiatal esophagectomy were excluded because of small numbers. The primary outcome of our study was the patient's self-reported health-related quality of life (HRQoL) at least 18 months after the surgery. The secondary outcomes of our study were perioperative complications, length of stay, recurrence, and mortality.

Quantitative Assessment of Gastric Conduit Dimensions

We examined medical records to retrieve the initial postoperative CT scan of every patient included in our study. The protocol at our institution is to perform postoperative CT 6 weeks after surgery on the first follow-up visit. The scan was analyzed using Visage Imaging software 7.1.15 for Windows measuring the maximum width of the intrathoracic conduit (centimeters), length of the linear staple line (centimeters), and proximity of the anastomosis by correlation to the corresponding vertebral body. A single board-certified radiologist made all measurements to maximize consistency. The relative height of the anastomosis was determined by registering the vertebral body corresponding to the anastomosis (Figure 1). Multiplanar reconstructions were used to measure the maximum transverse diameter at the widest portion of the intrathoracic conduit (Figure 2). The length of the staple line of the conduit was measured by tracing the linear staple line from the anastomosis to its end point using Visage's Vessel tool (Lumen View), which allows for measurements of curved structures (Figure 3). Additionally, we obtained the most recent CT scans of patients who had a follow-up CT scan available after the initial scan. We collected the dimensional measurements as described previously.

Patient's Long-Term Quality of Life: Patient-Reported Health-Related Quality of Life

We retrospectively reviewed our prospectively collected divisional database to identify 293 patients who underwent esophagectomy for malignancy at our institution between 2018 and 2020. By reviewing the patient's electronic medical records, we identified 198 survivors. With the help of the research coordinator from the Institutional Review Board, we used a secure messaging system integrated into our electronic medical record to invite all 198 eligible survivors to participate in a 1-time HRQoL survey via an electronic invitation letter. The invitation letter included a detailed information sheet approved by our Institutional Review Board delineating the rationale, goal, risks, and benefits of our study. The voluntary nature of participation was emphasized. Participants provided implied consent by completing the patient-reported outcomes survey through a REDcap survey link.

We used the European Organization for the Research and Treatment of Cancer (EORTC) Quality of Life Questions Core 30 Module (QLQ-C30), a general quality of life questionnaire, in combination with the Esophagus 18 Module (OES-18), an esophageal cancer-specific quality of life questionnaire.[6,7] The EORTC modules are widely accepted as a reliable and precise tool for measuring the quality of life of patients with cancer in clinical research settings. EORTC QLQ-C30 is a comprehensive questionnaire consisting of 30 items evaluating the holistic quality of life of individuals with different types of cancer (Figure E1). The OES-18 looks at esophageal cancer–specific symptoms such as dysphagia, reflux, and odynophagia that are common after esophagectomy.[7] The OES-18 esophageal disease–specific module is organized into 4 main categories: reflux, eating function, dysphagia, and odynophagia, along with individual items addressing symptoms including cough, dry mouth, and difficulty swallowing. To obtain a more granular understanding of disease-specific symptoms, we individually examined the association between conduit dimensions and each of the 18 questions in the esophageal disease–specific module.

The EORTC questionaries use response options that vary from "not at all" to "very much," except for the global quality of life scale, which offers 7 response options that range from "very poor" to "excellent." We used the EORTC scoring system, which involves transforming all responses linearly to a range of 0 to 100.[8,9]

Perioperative Outcomes: Complications, Length of Stay, and Mortality

Patient characteristics, operative factors, and perioperative outcomes were collected retrospectively by querying our prospectively collected database. The Institutional Review Board waived the need to obtain additional consent for the retrospectively collected data. Perioperative

FIGURE 1. Radiographical measurement of relative anastomotic height (vertebra)

complications examined in our study were pulmonary complications (chylothorax, aspiration pneumonia, pleural effusion, pneumothorax, respiratory insufficiency, acute respiratory distress syndrome, copious secretions, pulmonary embolism), cardiovascular complications (atrial fibrillation, ventricular fibrillation, myocardial infarction, pulseless electrical activity arrest, pericardial effusion, pericarditis), esophageal leak/stricture, and recurrent laryngeal nerve injury. Our study also examined the length of stay after surgery (measured in days), cancer recurrence, and time to death with respect to conduit dimensions.

Covariates and Descriptive Variables

The patient-level and surgeon-level baseline characteristics were included in the analyses as covariates to adjust for potential confounding. The patient-level covariates included age, gender, Charlson Comorbidity Index, neoadjuvant therapy (chemotherapy, radiation, immunotherapy), cancer stage (TNM classification by the 8th edition of the American Joint Committee on Cancer), surgical approach (minimally invasive, open), surgical type (McKeown, Ivor Lewis), tumor location (distance from the incisors), and pathology. Additionally, we included surgeons' years of experience (years since graduation of cardiothoracic fellowship) as a factor to address potential confounding at the surgeon level, because it may represent the experience of the surgeons. A model-based adjustment of clustering by surgeons such as a linear mixed effect model was deemed not suitable because of the low number of surgeons and the low number of patients within surgeons. All regressions also included all 3 conduit dimensions simultaneously because they are likely to be correlated with each other and may affect the outcomes.[10]

Statistical Analysis

Descriptive characteristics of the sample were presented separately by esophagectomy procedure type (Table 1). To assess the associations between conduit dimensions (staple line length, maximum conduit width, and anastomotic proximity) and outcomes, linear regressions were performed for continuous outcomes, and logistic regressions were performed for binary outcomes, adjusting for the covariates listed above. Firth's bias correction was applied for potential separation bias for logistic regressions.[11] In separate analyses, interaction terms between each dimension and esophagectomy procedure type (McKeown, Ivor Lewis) were included to test for potential heterogeneity (Table 2). For the dimension-outcome pairs with statistically significant interactions, marginal mean differences for continuous outcomes and marginal odds ratios for binary outcomes were provided as measures of associations, and their standard errors were calculated with the delta method. A Cox proportional hazards regression assessed the associations between conduit dimensions and time to death, adjusting for the potential confounders listed above. All analyses were conducted using R 4.1.1 (R Core Team, 2020).

RESULTS

Demographics

A total of 283 patients were identified to have undergone McKeown or Ivor Lewis esophagectomy for cancer at our institution from 2018 to 2020. A total of 47 patients were female, and 236 patients were male; 89 patients underwent McKeown esophagectomy, and 194 patients underwent Ivor Lewis esophagectomy. There was no significant difference in body mass index, mortality, pathologic stage, surgical technique (open vs minimally invasive), neoadjuvant therapy (chemo, radiation, immunotherapy), concomitant pyloromyotomy/pyloroplasty, and postsurgical dilation between those who underwent McKeown esophagectomy and those who underwent Ivor Lewis esophagectomy (Table 1). Histology significantly differed between the 2 groups, adenocarcinoma being more prevalent in Ivor Lewis than McKeown esophagectomy (88.14% vs 76.40, $P = .021$). The gastric conduit's mean staple length (24.94 vs 23.84 cm, $P = .065$) and intrathoracic conduit maximum width (4.69 vs 4.79 cm, $P = .502$) did not differ between McKeown and Ivor Lewis procedures. The proximity of the anastomosis relative to the vertebral column was significantly different, with the McKeown procedure having more cephalad anastomosis ($P < .001$). Patients without an available follow-up CT scan were excluded from the analysis (n = 23) (Figure 4). Of 198 eligible patients recruited to participate in the EORTC QLQ-C30 and OES-18 questionaries, 57 patients responded and were enrolled in our HRQoL analyses. Outcomes analyses were performed in all patients with dimensional measurements from their first postoperative CT scans, along with their breakdown (n = 260) (Table E1). For 158 patients who had more than 1 CT scan after surgery, we analyzed the change in the dimensions of the conduit between the first postoperative CT scan and the most recent postoperative CT scan (Table 2).

Crude comparisons of perioperative outcomes between McKeown and Ivor Lewis esophagectomies showed that the McKeown group had significantly more pulmonary complications, recurrent laryngeal nerve injury/dysfunction, and wound complications. However, there was no significant difference in HRQoL scores between the 2 groups (Table E2).

Association Between Anastomotic Height and Perioperative Outcomes and Long-Term Quality of Life

After controlling for confounders, our study revealed that a more proximal anastomosis was linked to an increased risk of pulmonary complications (odds ratio, 1.49, 95%

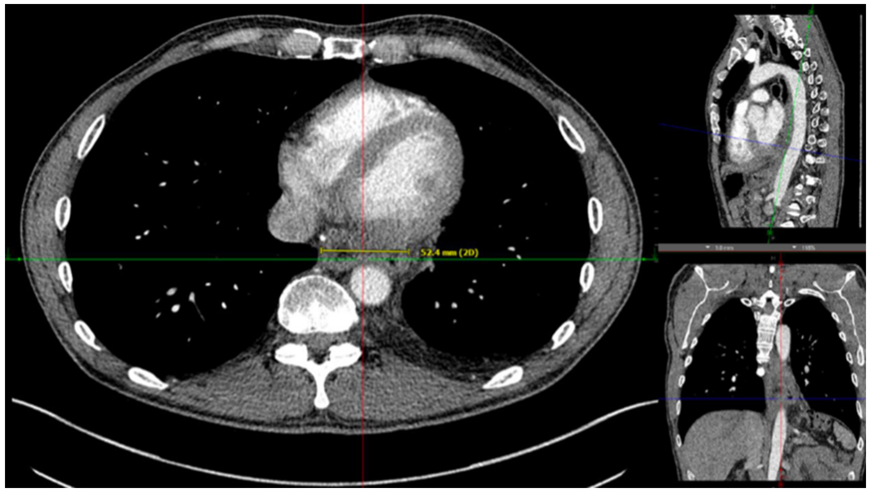

FIGURE 2. Radiographical measurement of maximum intrathoracic conduit width (centimeters)

CI, 1.09-2.03) but a lower recurrence rate in patients after esophagectomy (odds ratio, 0.73, 95% CI, 0.55-0.97) (Table 2). Regarding the quality of life, a more proximal anastomosis was independently associated with greater long-term insomnia, at least 18 months from surgery (β: 5.99, 95% CI, 0.22-11.75) (Table 3).

FIGURE 3. Radiographical measurement of the stapled line length (centimeters).

TABLE 1. Baseline characteristics of all patients who underwent McKeown or Ivor Lewis esophagectomy for malignancy between 2018 and 2020

Variables	McKeown	Ivor Lewis	P value
n	89	194	
Age, mean (SD), y	65.00 (9.63)	65.75 (8.66)	.513
Gender (%)			
Female	20 (22.47)	27 (13.92)	.104
Male	69 (77.53)	167 (86.08)	
BMI, mean (SD)	27.13 (5.20)	27.67 (5.12)	.413
Mortality (%)			
Alive	54 (60.67)	129 (66.49)	.414
Deceased	35 (39.33)	65 (33.51)	
Histology (%)			
Adenocarcinoma	69 (77.52)	171 (88.14)	.021
Adenosquamous carcinoma	0 (0.00)	1 (0.52)	
Neuroendocrine carcinoma	1 (1.12)	0 (0.00)	
Poorly differentiated carcinoma	0 (0.00)	3 (1.55)	
Squamous cell carcinoma	19 (21.35)	19 (9.79)	
Pathologic stage (TNM 8th) (%)			
0	14 (15.73)	48 (24.74)	.195
1	21 (23.60)	40 (20.62)	
2	26 (29.21)	36 (18.56)	
3	19 (21.35)	48 (24.74)	
4	9 (10.11)	22 (11.34)	
Surgical approach (%)			
Minimally invasive	77 (86.52)	171 (88.14)	.848
Open	12 (13.48)	23 (11.86)	
Neoadjuvant therapy (%)			
No	23 (25.84)	55 (28.35)	.768
Yes	66 (74.16)	139 (71.65)	
Stapled length, cm, mean (SD)	24.94 (5.27)	23.84 (4.02)	.065
Maximum width cm, mean (SD)	4.69 (1.07)	4.79 (1.22)	.502
Height (vertebral column) (%)			
C7	13 (14.61)	1 (0.52)	<.001
T1	29 (32.58)	3 (1.55)	
T2	35 (39.33)	8 (4.12)	
T3	3 (3.37)	30 (15.46)	
T4	1 (1.12)	71 (36.60)	
T5	1 (1.12)	46 (23.71)	
T6	1 (1.12)	15 (7.73)	
T7	0 (0.00)	2 (1.03)	
T8	0 (0.00)	1 (0.52)	
Missing	6 (6.74)	17 (8.76)	
Concomitant pyloric intervention (%)			
None	83 (93.26)	167 (86.08)	.138
Pyloromyotomy	2 (2.25)	16 (8.25)	
Pyloroplasty	4 (4.49)	11 (5.67)	
Postoperative esophageal dilation (%)			
No	38 (42.70)	100 (51.55)	.21
Yes	51 (57.30)	94 (48.45)	

BMI, Body mass index.

Association Between Maximum Conduit Width and Perioperative Outcomes and Long-Term Quality of Life

After controlling for confounders, our study revealed that an increased maximum intrathoracic conduit width (centimeters) on the first postoperative CT scan was significantly associated with greater trouble enjoying meals (β: 10.74, 95% CI, 2.81-18.67) and greater acid or bile reflux (β: 8.41, 95% CI, 1.68-21.88) at least 18 months from surgery (Table 4). These adverse effects of a wider maximum width on long-term quality of life were more pronounced after Ivor Lewis esophagectomy compared with McKeown esophagectomy (Table 2). The discrepancies between the Ivor Lewis and McKeown procedures were found to be significant in overall HRQoL (*P* value: .026), eating experience (*P* value: .002), and early satiety (*P* value: .017).

Association Between Conduit Stapled Line Length and Outcomes and Long-Term Quality of Life

After controlling for confounders, a longer conduit stapled line length on the first postoperative CT scan was independently associated with an increased length of hospital stay (β: 0.44, 95% CI, 0.19-0.70) (Table 5). However, a longer stapled line was correlated with fewer issues related to insomnia (β: −1.67, 95% CI, −3.11 to −0.23), less appetite loss (β: −2.78, 95% CI, −4.72 to −0.85), less dysphagia (β: −2.06, 95% CI, −3.67 to −0.44), and significantly enhanced "social" (β: 1.97, 95% CI, 0.31-3.63), "role" (β: 2.11, 95% CI, 0.36-3.86), and "physical" (β: 1.15, 95% CI, 0.11-2.19) aspects of the patient's long-term quality of life at least 18 months since surgery (Table 4).

Comparison of the Conduit Dimensions Between the Initial Postoperative Computed Tomography Scan and the Most Recent Postoperative Computed Tomography Scan

We measured the average length of the stapled line and maximum intrathoracic width of the conduit on the first postoperative CT scan and the most recent CT scan in 158 patients. Our analysis revealed that the average maximum width of the intrathoracic conduit did not change between these time points. However, the average length of the stapled line was significantly shorter on the most recent CT scan than on the first CT scan (β: −1.10, 95% CI, −1.38 to −0.83) (Table 6).

DISCUSSION

According to studies, the HRQoL of most patients undergoing esophagectomy returns to presurgery levels approximately 2 years after the procedure.[12,13] However, some patients continue to experience decreased quality of

TABLE 2. Heterogeneity in association between conduit dimensions and outcomes depending on the type of surgery (McKeown, Ivor Lewis)

Variables	Ivor-Lewis	McKeown	Interaction *P* value
Stapled line length (cm)			
Esophageal leak/stricture OR (95% CI)	0.92 (0.83-1.03)	1.09 (0.97-1.22)	.034*
Maximum conduit width (cm)			
Global Health Status β (95% CI)	−6.47 (−12.08 to −0.85)*	3.53 (−3.25 to 10.31)	.026*
Have you had trouble enjoying your meals? β (95% CI)	19.85 (10.16-29.53)*	−4.49 (−16.18 to 7.2)	.002*
Have you felt full up too quickly? β (95% CI)	8.96 (−0.29 to 18.21)	−8.62 (−19.79 to 2.54)	.017*

All values were adjusted for covariates age, gender, Charlson comorbidity index, neoadjuvant therapy, cancer stage, and surgical approach (open, minimally invasive), surgical type (McKeown, Ivor Lewis), tumor location (distance from the incisors), pathology, surgeon's year since fellowship graduation. All regressions also included all 3 conduit dimensions simultaneously because they are likely to be correlated with each other and may affect the outcomes. *OR,* Odds ratio. *Statistically significant result.

life even after this period. We hypothesized that variations in the early postoperative dimensions of the gastric conduit could predict future gastric conduit dysfunction, which might explain these persistent symptoms. In our study, we observed that anatomic factors related to the surgical reconstruction of the gastric conduit, namely, anastomotic proximity, maximum intrathoracic conduit width, and conduit stapled line length, as measured on the first postoperative CT scans, were each independently associated with the long-term quality of life experienced by patients who underwent esophagectomy for malignancy. Figure 5 shows a Graphical Abstract of the study.

In esophagectomy for malignancy, the proximity of the anastomosis is primarily determined by the adequacy of a negative margin, which is influenced by the tumor's location. Granted a negative margin, the literature presents conflicting views on the ideal height of the anastomosis. Advocates of more distal esophagogastric anastomosis argue that more proximal anastomosis poses a risk of compromised blood supply, potentially leading to increased leaks and strictures.[14] On the other hand, proponents of more proximal anastomosis argue that a proximal location leads to improved conduit emptying and reduced gastrointestinal symptoms including reflux.[15,16] For example, Hasan and colleagues[17] in 2020 showed that the proximity of the anastomosis was associated with less patient-reported reflux, regardless of surgery type. On the basis of the available evidence, we hypothesized that more cephalad anastomosis may be associated with sustained improved quality of life with regard to gastric emptying and reflux by way of reducing intrathoracic conduit redundancy. Our study showed no association

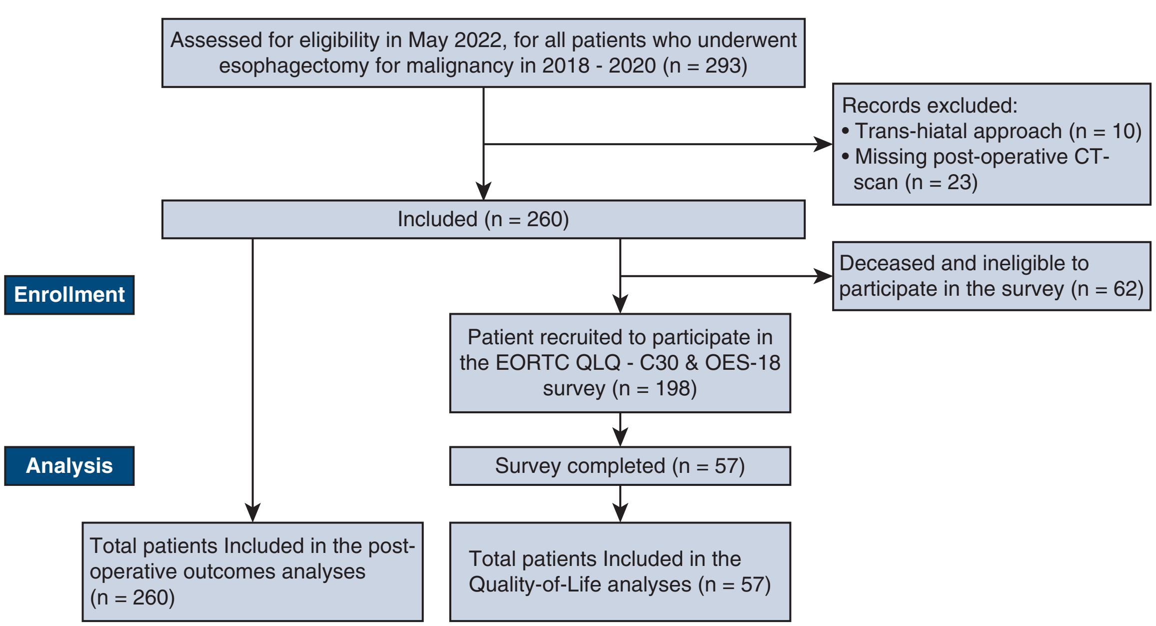

FIGURE 4. Study enrollment flow chart.

TABLE 3. Conduit dimensions and long-term quality of life (European Organization for the Research and Treatment of Cancer–Quality of Life Questions Core 30 Module)

Variables	Stapled line length (cm)	Maximum conduit width (cm)	Anastomotic height (vertebra)
Global Health Status β (95% CI)	−0.11 (−1.37 to 1.16)	−2.57 (−6.87 to 1.74)	−4.68 (−9.74 to 0.37)
Financial difficulties β (95% CI)	0.22 (−1.27 to 1.7)	2.22 (−2.84 to 7.27)	−2.47 (−8.4 to 3.47)
Cognitive function β (95% CI)	1.06 (−0.13 to 2.25)	−0.88 (−4.93 to 3.18)	0.63 (−4.13 to 5.39)
Social function β (95% CI)	1.97 (0.31-3.63)*	−3.91 (−9.57 to 1.75)	1.28 (−5.36 to 7.92)
Role function β (95% CI)	2.11 (0.36-3.86)*	−1.25 (−7.2 to 4.71)	−0.3 (−7.29 to 6.68)
Emotional function β (95% CI)	0.8 (−0.85 to 2.46)	−5.25 (−10.89 to 0.4)	3.83 (−2.79 to 10.46)
Physical function β (95% CI)	1.15 (0.11-2.19)*	−2.78 (−6.34 to 0.77)	3.48 (−0.69 to 7.66)
Fatigue β (95% CI)	−1.2 (−2.76 to 0.35)	1.62 (−3.68 to 6.92)	−2.76 (−8.98 to 3.45)
Insomnia β (95% CI)	−1.67 (–3.11 to –0.23)*	−3.98 (−8.9 to 0.93)	5.99 (0.22-11.75)*
Dyspnea β (95% CI)	−1.43 (−3.03 to 0.16)	2.27 (−3.16 to 7.7)	0.26 (−6.11 to 6.64)
Appetite loss β (95% CI)	−2.78 (–4.72 to –0.85)*	1.29 (−5.33 to 7.9)	−6.58 (−14.32 to 1.17)
Nausea/vomiting β (95% CI)	−0.08 (−1.51 to 1.36)	3.05 (−1.84 to 7.94)	−1.19 (−6.92 to 4.55)
Diarrhea β (95% CI)	0.75 (−0.97 to 2.46)	−1.48 (−7.32 to 4.36)	−0.66 (−7.51 to 6.2)
Constipation β (95% CI)	−1.37 (−2.84 to 0.1)	−2.78 (−7.79 to 2.23)	0.39 (−5.49 to 6.27)

All values were adjusted for covariates age, gender, Charlson Comorbidity Index, neoadjuvant therapy, cancer stage, and surgical approach (open, minimally invasive), surgical type (McKeown, Ivor Lewis), tumor location (distance from the incisors), pathology, surgeon's year since fellowship graduation. All regressions also included all 3 conduit dimensions simultaneously because they are likely to be correlated with each other and may affect the outcomes. *Statistically significant result.

between anastomotic proximity and anastomotic leak/stricture and long-term symptoms of dysphagia, postprandial fullness, and reflux. Instead, our study revealed that more cephalad anastomosis was linked to increased perioperative pulmonary complications and long-term insomnia (Tables 3 and 5). This may be because the proximity of the acid-producing conduit to the upper esophageal sphincter might increase the risk of aspiration, leading to higher pulmonary complications and long-term insomnia in patients. Additionally, we found more cephalad anastomosis was associated with decreased odds of cancer recurrence independent of the tumor location (distance from incisor) and histology, suggesting a more generous cephalad proximal margin may subsequently reduce the risk of recurrence (Table 5). A careful assessment of the balance of risks and benefits should be performed when making decisions in this regard.

The length of the conduit is influenced by various factors, including the proximity of anastomosis, the extent of gastric resection, the conduit's mobility, and the surgeon's intraoperative judgment on tension. Furthermore, the surgical procedure itself spans multiple fields (abdomen, chest, and possibly neck), making it challenging to standardize the intraoperative decisions and measurement of the final conduit length, thus heavily relying on the surgeon's experience. Consequently, there has been a scarcity of evidence concerning conduit length. To our knowledge, our group was the first to investigate the association between linear staple line length of the conduit with patient outcomes and quality of life after esophagectomy. Our approach offers the advantage of providing the measurement of length in a standardized manner.

The process of reconstructing the gastric conduit involves firing a series of linear staplers along the greater curvature

TABLE 4. Conduit dimensions and esophageal-cancer specific long-term quality of life (Esophagus 18 Module)

Variables	Stapled line length (cm)	Maximum conduit width (cm)	Anastomotic height (vertebra)
Could you eat solid food? β (95% CI)	1.64 (0.01-3.26)	2.77 (−2.78 to 8.32)	−1.76 (−8.26 to 4.75)
Could you eat liquidized or soft food? β (95% CI)	0.78 (−0.78 to 2.34)	1.29 (−4.03 to 6.6)	−0.68 (−6.92 to 5.56)
Could you drink liquids? β (95% CI)	1.1 (−0.69 to 2.88)	5.89 (−0.21 to 11.99)	−2.51 (−9.67 to 4.64)
Have you had trouble with swallowing your saliva? β (95% CI)	−0.07 (−2.54 to 2.4)	2.71 (−5.71 to 11.14)	−3.18 (−13.06 to 6.71)
Have you choked when swallowing? β (95% CI)	0.83 (−1.18 to 2.83)	−0.61 (−7.45 to 6.23)	−0.8 (−8.83 to 7.23)
Have you had trouble enjoying your meals? β (95% CI)	−1.16 (−3.49 to 1.16)	10.74 (2.81-18.67)*	−7.74 (−17.05 to 1.56)
Have you felt full up too quickly? β (95% CI)	−1.99 (−4.1 to 0.13)	2.02 (−5.18 to 9.23)	−4.32 (−12.78 to 4.13)
Have you had trouble with eating? β (95% CI)	−2.06 (−3.67 to −0.44)*	−0.16 (−5.67 to 5.34)	−4.71 (−11.18 to 1.75)
Have you had trouble with eating in front of other people? β (95% CI)	−1.33 (−2.85 to 0.2)	5.07 (−0.14 to 10.28)	−5.08 (−11.2 to 1.03)
Have you had a dry mouth? β (95% CI)	−0.68 (−2.69 to 1.32)	−1.91 (−8.75 to 4.93)	2.91 (−5.12 to 10.94)
Did food and drink taste different from usual? β (95% CI)	−0.32 (−1.79 to 1.16)	−0.27 (−5.31 to 4.76)	−2.29 (−8.19 to 3.61)
Have you had trouble with coughing? β (95% CI)	−0.91 (−2.95 to 1.12)	−2.75 (−9.69 to 4.18)	3.64 (−4.5 to 11.78)
Have you had trouble with talking? β (95% CI)	−0.65 (−1.69 to 0.38)	0.17 (−3.36 to 3.69)	2.12 (−2.02 to 6.26)
Have you had acid indigestion or heartburn? β (95% CI)	0.97 (−1.2 to 3.13)	3.1 (−4.27 to 10.48)	3.7 (−4.95 to 12.36)
Have you had trouble with acid or bile coming into your mouth? β (95% CI)	0.4 (−1.85 to 2.64)	8.41 (0.77-16.05)*	−1.65 (−10.62 to 7.32)
Have you had pain when you eat? β (95% CI)	−1.59 (−3.33 to 0.16)	−2.05 (−8 to 3.9)	4.6 (−2.38 to 11.58)
Have you had pain in your chest? β (95% CI)	0.56 (−0.52 to 1.63)	0.54 (−3.12 to 4.2)	2.68 (−1.62 to 6.98)
Have you had pain in your stomach? β (95% CI)	−0.28 (−2.39 to 1.83)	−1.13 (−8.32 to 6.05)	−3.58 (−12.01 to 4.86)

All values were adjusted for covariates age, gender, Charlson Comorbidity Index, neoadjuvant therapy, cancer stage, and surgical approach (open, minimally invasive), surgical type (McKeown, Ivor Lewis), tumor location (distance from the incisors), pathology, surgeon's year since fellowship graduation. All regressions also included all 3 conduit dimensions simultaneously because they are likely to be correlated with each other and may affect the outcomes. *Statistically significant result.

of the stomach. The location where the stapled line begins in the antrum and the amount of stomach resected near the fundus is largely a result of the surgeon's decision-making. We hypothesized that a longer conduit stapled line length, as measured on the first CT scan, would serve as a predictor of enhanced HRQoL for patients via enhanced gastric emptying and reduced issues of retention, reflux, and intrathoracic stomach syndrome (including symptoms such as palpitations and chest discomfort after eating). The rationale behind this prediction was that given the anastomotic height as a constant, a longer stapled line may translate to the construction of an optimal conduit that is straight and narrow with an optimal infra-diaphragmatic antral reservoir.[4,18-20] Consistent with our hypothesis, our results showed that a longer stapled length was independently associated with less dysphagia, improved appetite, and less insomnia at least 18 months after surgery (Table 4). In addition, longer stapled length was associated with better patient-reported outcomes in social, role, and physical functioning (Table 3). We believe that longer conduit stapled length may indicate nontensile, adequately sized conduits that avoid mechanical obstruction, particularly at the hiatus. This could imply a longer intra-abdominal conduit with a greater distance

TABLE 5. Conduit dimensions and perioperative outcomes, cancer recurrence, and mortality

Variables	Stapled line length (cm)	Maximum conduit width (cm)	Anastomotic height (vertebra)
Cardiac complication OR (95% CI)	1.02 (0.94-1.11)	1.04 (0.76-1.42)	1.27 (0.91-1.79)
Pulmonary complication OR (95% CI)	1.04 (0.96-1.12)	0.88 (0.66-1.17)	1.49 (1.09-2.03)*
Recurrent laryngeal nerve palsy/dysfunction OR (95% CI)	1.05 (0.96-1.14)	1.19 (0.86-1.65)	0.98 (0.69-1.39)
Anastomotic leak/necrosis OR (95% CI)	1.02 (0.93-1.12)	1.1 (0.79-1.55)	1.36 (0.92-2.02)
Genitourinary complications OR (95% CI)	1.11 (0.98-1.26)	0.88 (0.54-1.46)	1.11 (0.69-1.76)
Wound complications OR (95% CI)	1.01 (0.87-1.16)	1.2 (0.7-2.05)	0.94 (0.54-1.63)
Cancer recurrence OR (95% CI)	1.06 (0.99-1.14)	1.08 (0.83-1.4)	0.73 (0.55-0.97)*
Length of stay β (95% CI)	0.44 (0.19-0.7)*	−0.55 (−1.48 to 0.37)	0.06 (−0.91 to 1.02)
Esophageal dilation OR (95% CI)	0.96 (0.9-1.03)	0.85 (0.68-1.07)	0.92 (0.72-1.17)
Mortality OR (95% CI)	1.02 (0.97-1.08)	1.00 (0.81-1.22)	1.20 (0.94-1.53)

All values were adjusted for covariates age, gender, Charlson Comorbidity Index, neoadjuvant therapy, cancer stage, and surgical approach (open, minimally invasive), surgical type (McKeown, Ivor Lewis), tumor location (distance from the incisors), pathology, surgeon's year since fellowship graduation. All regressions also included all 3 conduit dimensions simultaneously because they are likely to be correlated with each other and may affect the outcomes. *OR,* Odds ratio. *Statistically significant result.

from the pylorus, which might result in a decreased occurrence of bile reflux, and a narrower distal antrum, decreasing the chances of a redundant antral reservoir that acts as a "sink-trap."

Several studies have explored the association between the width of the gastric conduit and the outcomes. In general, creating a tubular gastric conduit with a diameter of less than 5 cm has been advised.[10,18,21] Rates of anastomotic leak and reflux esophagitis are lower in a reconstructed gastric conduit with a narrower diameter of 4 to 6 cm than in a gastric conduit where the entire stomach is used.[18] Likewise, having a gastric conduit with a diameter less than 4 cm is associated with a decreased risk of developing anastomotic strictures after esophagectomy compared with having a gastric conduit with a diameter greater than 5 cm.[21] To the best of our knowledge, no quantitative data exist on the association between the width of the conduit and the long-term quality of life. We hypothesized that the maximum intrathoracic conduit width shown on the first postoperative CT scan would help predict the long-term consequences of delayed gastric emptying and reflux. Our results indicate that for long-term survivors of an esophagectomy, a wider conduit is associated with worse HRQoL, including difficulty enjoying meals and increased acid/bile reflux (Table 4). The wider conduit width was more strongly associated with poor HRQoL and worse eating function in patients who underwent Ivor Lewis esophagectomy than in patients who underwent McKeown esophagectomy (Table 2). Our results suggest narrowness of the gastric conduit may be more important for the function of intrathoracic anastomosis esophagectomies.

TABLE 6. Comparison of the dimensional measurements between the initial postoperative computed tomography scan and the most recent postoperative computed tomography scan

Variables	Mean difference	*P* value
Maximum conduit width (cm) β (95% CI)	0.11 (−0.05 to 0.27)	.173
Stapled line length (cm) β (95% CI)	−1.10 (−1.38 to −0.83)	<.001

Complications causing dilation of the conduit, such as para-conduit herniation, are known to have a negative impact on the quality of life for patients.[3,22] We hypothesized that, on average, the conduit widens over time, which could partially account for the variability in the long-term quality of life in patients. To investigate this hypothesis, we examined the change in the maximum intrathoracic width of the conduit by comparing the first postoperative CT scan with the most recent one. Our analysis revealed that the average maximum width of the intrathoracic conduit remained consistent between these time points, suggesting that, apart from a small subset of

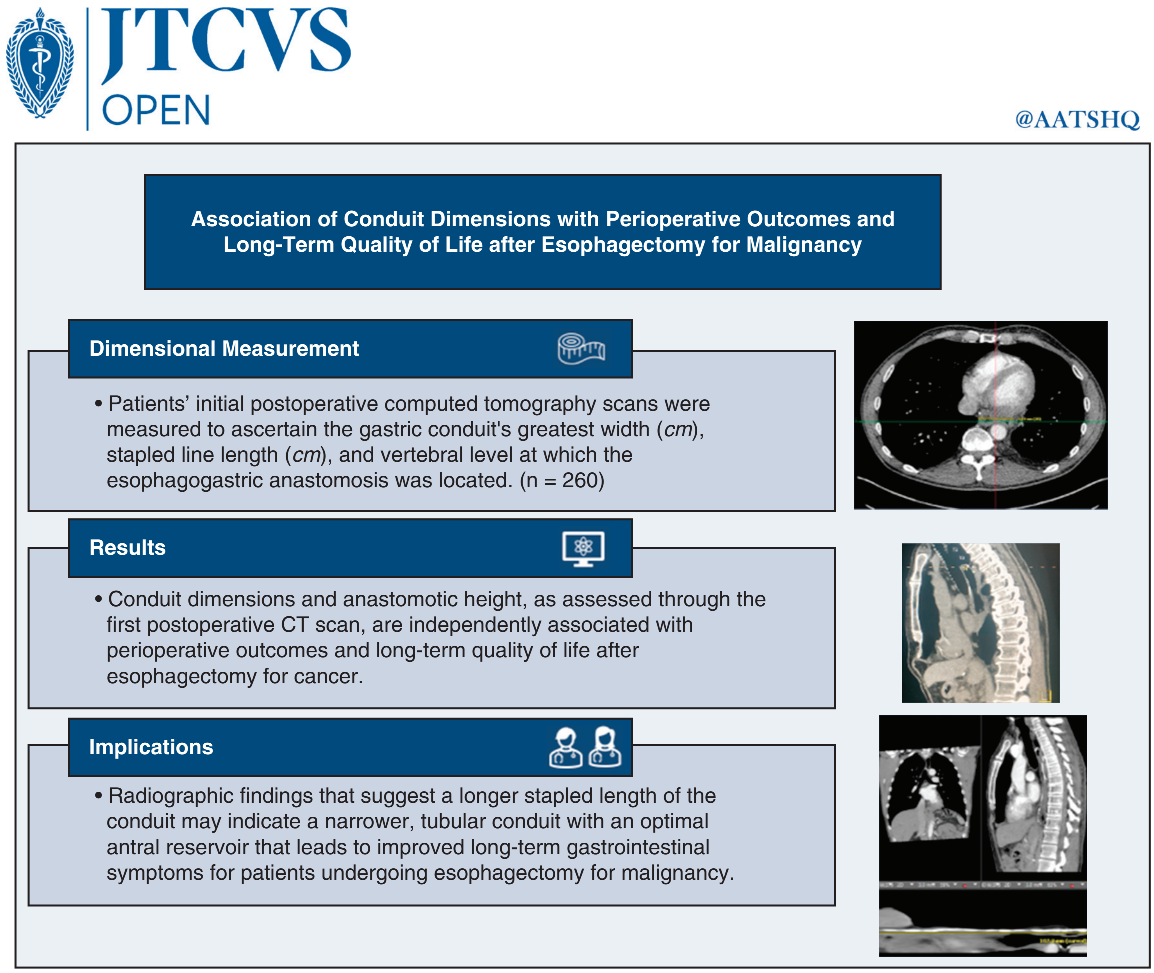

FIGURE 5. Graphical Abstract.

patients, the width of the conduit typically remains stable over time.

Study Limitations

There are important limitations in our study. First, the absence of data on baseline quality of life prevented us from controlling for potential bias that may have arisen due to variations in the individual's baseline quality of life. In addition, the duration between surgery and survey completion varied among participants, ranging from 18 months to 45 months. However, we did not expect the variance in duration from surgery to survey to be a significant confounding factor in our study, because all the patients were long-term survivors of esophageal cancer who likely would have attained stability in their long-term quality of life.[12,23,24]

Sampling bias was a limitation of our study. Our study was from a single-center study that relied on patients' voluntary participation in an electronically distributed survey. Therefore, our sample population may not accurately represent the average experience of long-term quality of life of esophageal cancer survivors. In addition, the impact of attrition bias should be considered while interpreting our data, because many eligible patients had already died during our recruitment period. However, our analysis of mortality data revealed that conduit dimensions were not independently associated with survival, suggesting that attrition bias may be negligible (Table 5). Finally, the small sample size limited the power of our ability to draw conclusions about the association between conduit dimensions and long-term quality of life.

Another limitation is that the inferences we drew about surgical planning were based on the assumption that the dimensional measurements of the conduit measured on the patient's first postoperative CT scan align with the dimensions of the conduit created by the surgeons during the operation. We acknowledge that the dimensions of the conduit are dynamic, and the static cross-sectional view provided by the CT scan may not accurately estimate the conduit dimensions. Based on our analysis, there was no statistically significant difference between the mean maximum width of the conduit from the first postoperative

CT scan with the mean maximum width from the most recent CT scan (Table 6). Despite these limitations, we believe that the initial postoperative CT scan can be a reliable indicator of the conduit's inherent maximum width.

CONCLUSIONS

Our study suggests that conduit dimensions and proximity of the anastomosis, as assessed from the first postoperative CT, may be independently linked to long-term quality of life after esophagectomy for cancer.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://www.aats.org/resources/impact-of-conduit-dimensions-on-long-term-quality-of-life-after-esophagectomy-for-malignancy.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: anastomotic height, conduit dimensions, esophagectomy, gastric conduit, perioperative outcomes, quality of life

Generalized quality of life
- How would you rate your overall health?
- How would you rate your overall quality of life?

Physical function
- Do you have any trouble doing strenuous activities?
- Trouble with long walks?
- Trouble taking short walk outside of house?
- Do you need to stay in bed or a chair during the day?
- Do you need help with eating? Dressing? Washing yourself or using the toilet?

Role function
- Were you limited in doing your work?
- Were you limited in pursuing your hobbies/leisure activities?

Social function
- Has your physical condition or medical treatment interfered with your family life?
- Has your physical condition or medical treatment interfered with your social activities?

Cognitive function
- Have you had difficulty remembering things this past week?
- Have you had difficulty with your daily activities?

Emotional function
- Did you feel tense?
- Did you worry?
- Did you feel irritable?
- Did you feel depressed?

Fatigue
- Did you need to rest?
- Have you felt weak?
- Were you tired?

Nausea and vomiting
- Have you felt nauseated?
- Have you vomited?

Generalized pain
- Have you had pain in the past week?
- Did pain interfere with your daily activities?

Dyspnea
- Were you short of breath?

Insomnia
- Have you had trouble sleeping?

Appetite loss
- Have you lacked appetite?

Constipation
- Have you been constipated?

Diarrhea
- Have you had diarrhea?

Financial difficulties
- Have your physical condition or medical treatment caused you financial difficulties?

FIGURE E1. EORTC QLQ-C30 scales and questions.

TABLE E1. Differences in perioperative outcomes between McKeown and Ivor Lewis esophagectomies

EORTC QLQ-C30 scales and questions	McKeown	Ivor Lewis	*P* value
n	89	194	
Pulmonary complications (%)	32 (35.96)	32 (16.49)	.001*
Cardiovascular complications (%)	18 (20.22)	25 (12.89)	.156
Esophageal leak/stricture (%)	12 (13.48)	13 (6.70)	.101
Recurrent laryngeal nerve injury/dysfunction (%)	25 (28.09)	14 (7.22)	<.001*
Genitourinary complications (%)	6 (6.74)	8 (4.12)	.517
Wound complications (%)	9 (10.11)	2 (1.03)	.001*
Length of stay [mean (SD)]	13.72 (9.77)	10.69 (8.02)	.006*
Distribution of pulmonary complications			**Total (n = 283)**
Respiratory insufficiency (%)			36 (12.7)
Chylothorax (%)			19 (6.7)
Aspiration pneumonia (%)			13 (4.6)
Pleural effusion (%)			19 (6.7)
Respiratory failure (%)			8 (2.8)
Pneumothorax (%)			2 (0.7)
Copious secretion (%)			2 (0.7)
ARDS (%)			4 (1.4)
Pulmonary embolism (%)			2 (0.7)
Total (%)			64 (22.6)
Esophageal leak/stricture in McKeown and Ivor Lewis esophagectomies			**Total (n = 283)**
Esophageal leak (%)			21 (7.4)
Esophageal stricture without leak, (%)			4 (1.4)
Total (%)			25 (8.8)

ARDS, Acute respiratory distress syndrome. *Statistically significant result.

TABLE E2. Differences in long-term quality of life scores between McKeown and Ivor Lewis esophagectomies

Variables	McKeown	Ivor Lewis	*P* value
Generalized quality of life [mean (SD)]	82.02 (14.77)	71.51 (21.91)	.062
Financial difficulties [mean (SD)]	8.77 (15.08)	9.30 (20.99)	.921
Cognitive functional difficulties [mean (SD)]	88.60 (13.67)	87.98 (17.94)	.895
Social functional difficulties [mean (SD)]	76.32 (22.44)	76.74 (23.33)	.946
Role functional difficulties [mean (SD)]	81.58 (24.78)	78.68 (26.31)	.686
Emotional functional difficulties [mean (SD)]	85.96 (12.12)	80.04 (24.47)	.322
Physical functional difficulties [mean (SD)]	88.77 (16.93)	85.58 (15.32)	.467
Fatigue [mean (SD)]	25.73 (18.16)	29.20 (24.01)	.576
Insomnia [mean (SD)]	12.28 (16.52)	23.26 (22.46)	.061
Dyspnea [mean (SD)]	17.54 (20.39)	25.58 (25.03)	.224
Appetite loss [mean (SD)]	22.81 (29.51)	24.03 (28.48)	.878
Dysphagia [mean (SD)]	91.23 (13.14)	84.50 (20.59)	.196
Nausea and vomit [mean (SD)]	12.28 (14.53)	17.83 (22.83)	.334
Diarrhea [mean (SD)]	19.30 (23.08)	23.26 (25.75)	.567
Constipation [mean (SD)]	8.77 (15.08)	12.40 (23.03)	.532
Q31. Could you eat solid food? [mean (SD)]	85.96 (23.08)	81.40 (24.45)	.493
Q32. Could you eat liquidized or soft food? [mean (SD)]	94.74 (12.49)	86.82 (21.99)	.148
Q33. Could you drink liquids? [mean (SD)]	92.98 (17.84)	85.27 (23.35)	.205
Q34. Have you had trouble with swallowing your saliva? [mean (SD)]	14.04 (30.05)	17.83 (32.81)	.669
Q35. Have you choked when swallowing? [mean (SD)]	12.28 (16.52)	10.85 (26.94)	.832
Q36. Have you had trouble enjoying your meals? [mean (SD)]	33.33 (29.40)	36.43 (33.19)	.727
Q37. Have you felt full up too quickly? [mean (SD)]	64.91 (32.34)	51.16 (25.56)	.077
Q38. Have you had trouble with eating? [mean (SD)]	33.33 (31.43)	20.93 (19.28)	.061
Q39. Have you had trouble with eating in front of other people? [mean (SD)]	19.30 (32.04)	7.75 (16.00)	.062
Q40. Have you had a dry mouth? [mean (SD)]	17.54 (23.22)	24.81 (30.07)	.354
Q41. Did food and drink taste different from usual? [mean (SD)]	12.28 (19.91)	12.40 (21.85)	.983
Q42. Have you had trouble with coughing? [mean (SD)]	21.05 (22.80)	26.36 (32.17)	.519
Q43. Have you had trouble with talking? [mean (SD)]	5.26 (12.49)	8.53 (17.96)	.476
Q44. Have you had acid indigestion or heartburn? [mean (SD)]	24.56 (24.45)	37.98 (33.00)	.118
Q45. Have you had trouble with acid or bile coming into your mouth? [mean (SD)]	35.09 (32.34)	28.68 (28.71)	.439
Q46. Have you had pain when you eat? [mean (SD)]	19.30 (32.04)	9.30 (16.79)	.112
Q47. Have you had pain in your chest? [mean (SD)]	7.02 (13.96)	9.30 (18.29)	.63
Q48. Have you had pain in your stomach? [mean (SD)]	29.82 (33.14)	17.83 (21.02)	.09