



# Diaphragmatic herniation following total gastrectomy: review of the long-term experience of a tertiary institution

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## Abstract

**Purpose** Diaphragmatic herniation (DH) is a rare but potentially fatal event after total gastrectomy (TG). Despite being life-threatening, risk factors for postoperative DH have yet to be elucidated. We conducted a retrospective analysis to identify clinical characteristics of patients developing DH after TG, along with a comprehensive review of the published literature.

**Methods** Among 1361 consecutive patients undergoing TG for esophagogastric cancer between 1985 and 2013 in Toranomon Hospital, those requiring surgical intervention for postoperative DH were included. We also conducted a PubMed literature search on DH following TG.

**Results** Five patients (four males, one female), with a median age of 68 at DH surgery, were identified. Intervals between TG and DH repair ranged from 2.9 to 189.0 (median, 78.1) months. Four patients had needed emergency surgery. Three patients had undergone open TG and two others laparoscopic TG, suggesting a significantly higher incidence of DH after laparoscopic TG (3/1302 vs. 2/59,  $p = 0.017$ ). The diaphragmatic crus incision, creating the space for esophagojejunostomy, had been performed in all cases. The literature yielded seven relevant publications (16 patients). Intervals between TG and DH reduction ranged from 2 days to 36 months. All operations for DH had been carried out emergently.

**Conclusion** The risk of DH persisted after TG. DH is potentially a very late complication of TG, presenting as a surgical emergency. Laparoscopic TG was suggested to be a risk factor for postgastrectomy DH. Incising the crus might also be a predictor of DH. Measures to prevent DH, e.g., appropriate closure of the crus, would be recommended in minimally invasive TG.

**Keywords** Diaphragmatic hernia · Total gastrectomy · Gastric cancer · Esophagogastric junction cancer · Complication · Emergency

## Introduction

Gastrectomy with lymphadenectomy is the standard treatment for gastric cancer, which is now reportedly the third leading cause of cancer-related deaths worldwide [1]. The global incidence of cancers involving the gastric cardia and the esophagogastric junction has been rising, and the demand for total gastrectomy (TG) is hence growing [1]. TG is a highly complex surgical procedure which inevitably requires multiple anastomoses [2]. This complexity gives rise to anatomical challenges and the possible creation of

spaces for potential internal hernia formation. Internal hernia formation following TG reportedly occurs in an estimated 3–8% of cases, and most such herniations are, whether emergently or not, managed with surgical repair [3–5]. Sites of internal hernia orifices in a totally gastrectomized state might correspond to factors such as jejunojunction mesenteric defect, Petersen's defect, mesentery of the transverse colon, or, albeit rarely, a diaphragmatic defect including esophageal hiatus [6]. In particular, diaphragmatic herniation (DH) is a potentially severe complication associated with high morbidity and mortality, not only because of strangulated bowel obstruction and intestinal ischemia but also due to respiratory compromise with lung compression. Prophylaxis against postoperative DH is therefore of importance, but factors predicting risk, in terms of gastrectomy, have yet to be clarified. Detailed examination of the clinical features of post-TG DH is thus warranted.

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We retrospectively analyzed clinical characteristics of patients who developed symptomatic DH after undergoing TG for either gastric or esophagogastric junction cancer. In addition, given the limited data on the incidence, the timing of and risk factors for post-TG DH, we carried out a comprehensive review of the published literature with the aim of providing a summary of the features of this form of DH.

## Patients and methods

### Study population

Information from a database stored and maintained in Toranomon Hospital, Tokyo, Japan, was obtained retrospectively. We identified 1361 consecutive patients undergoing TG for either gastric or esophagogastric junction cancer between January 1985 and December 2013 in Toranomon Hospital. All subjects had, basically, undergone postoperative follow-up surveillance for at least 5 years after surgery or until death. Postoperative examinations routinely included physical examination, esophagogastroduodenoscopy, computed tomography, abdominal ultrasonography, and blood tests, in accordance with the guidelines of the Japan Esophageal Society [7] and the Japanese Gastric Cancer Association [8]. We estimated the postoperative occurrence of DH, defined as thoracic herniation of any abdominal contents through a defect in the diaphragm, and reviewed all potential subjects. DH cases with relevant symptoms requiring surgical treatment were included in our analysis.

Detailed clinicopathological factors for each patient were retrieved from hospital records. Our retrospective disease staging was based on the eighth edition of the TNM classification, established by the Union for International Cancer Control [9]. Our protocol was approved by the Toranomon Hospital Institutional Review Board of Clinical Research. As this study had a retrospective design, the need for informed consent from patients was waived.

### Surgical procedure

Surgical indications for and management of gastric and esophagogastric junction cancers fundamentally were in accordance with the treatment guidelines published by the Japanese Gastric Cancer Association [8].

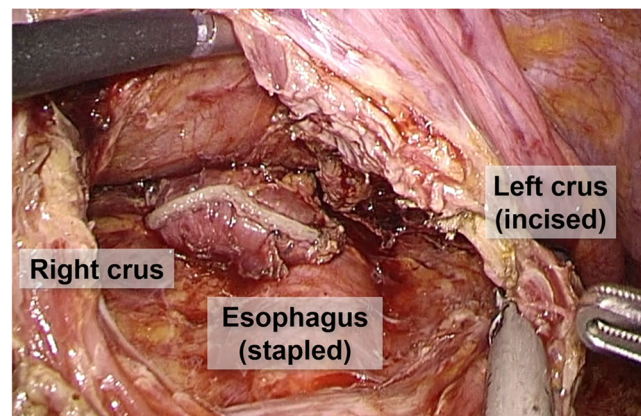
Reconstruction in open TG (1302 cases, 1985–2013) mainly employed Roux-en-Y esophagojejunostomy (842/1302 [64.7%]) or jejunal interposition (423/1302 [32.5%]). When tumor invasion had spread to the esophagogastric junction and/or the lower esophagus, the left thoracoabdominal approach was an option (365/1302 [28.0%]) [10]. Anastomotic techniques for performing esophagojejunostomy included hand-sewing and circular stapling (including usage of OrVil™, transorally inserted anvil [11]).

Laparoscopic TG was introduced in our department in November 2008 and has since mainly been applied to earlier-stage gastric or esophagogastric junction cancers, which are difficult to curatively resect with partial gastrectomy (59 cumulative cases through December 2013). The main approach to reconstruction in laparoscopic TG was Roux-en-Y, with intracorporeal esophagojejunostomy created by OrVil™ or the overlap method (side-to-side stapled anastomosis) [12]. When creating the esophagojejunal anastomosis, especially during resection of a gastric cancer located at a relatively high site (cardia) or an esophagogastric junction cancer, we partially incised the left diaphragmatic crus muscle with an ultrasonic scalpel to broaden the working space as preparation for anastomotic procedures (Fig. 1).

### Literature review

A comprehensive literature search using the terms “diaphragmatic hernia” and “total gastrectomy” (in combination with the Boolean operators AND) was conducted employing PubMed, focusing on the period from January 1990 to May 2019. Relevant articles were identified, and we also searched the references for other case reports or case series which might be suitable for inclusion in our analysis. Studies examining DH (including hiatal hernia) as a complication related to TG were deemed to be acceptable for inclusion. Articles written in a language other than English were excluded. Articles in the so-called “Letter to the Editor” or “How-I-Do-It” format were also excluded.

We inserted data from each study into a spreadsheet to summarize patient demographics, time intervals from TG to DH surgery, and details of the surgical techniques used for TG and in DH reduction. Outcome parameters described in the literature, such as rate of DH, follow-up duration, and follow-up rate, were investigated as well.



**Fig. 1** During total gastrectomy, the esophageal hiatus is broadly enlarged by incising the left crus of the diaphragm as preparation for esophagojejunostomy

## Statistical analysis

Differences in categorical variables were compared using Fisher's exact test. *P*-values <0.05 (two-tailed) were considered to indicate a statistically significant difference. All statistical analyses were carried out using JMP Pro version 14.2.0 (SAS Institute, Cary, NC, USA).

## Results

### Characteristics of patients developing DH after TG

In total, five patients (four males and one female), with a median age of 68 (range: 64–72) years at DH surgery, were identified (5/1361 [0.4%]). Characteristics of these patients are shown in Table 1. With regard to approaches used for the prior gastrectomy, three patients had undergone open TG, the other two laparoscopic TG, denoting a significantly higher incidence of postoperative DH after laparoscopic TG than open TG (3/1302 [0.2%] vs. 2/59 [3.4%], *p* = 0.017). A left thoracoabdominal approach had been used in two of the three patients receiving open TG, with the incidence of DH being somewhat higher in the laparotomy cohort with left thoracoabdominal incision than those without (2/365 [0.5%] vs. 1/937 [0.1%], *p* = 0.19). Anastomotic techniques included circular stapling (*n* = 3) and the overlap method (*n* = 2). Incision of the diaphragmatic crus, for the purpose of securing the space for esophagojejunostomy construction, had been performed in all five cases (Fig. 1).

Intervals between TG and DH repair ranged from 2.9 to 189.0 months (median, 78.1 months). Emergency surgery had been required in four patients, all of whom had developed acute symptoms such as intense abdominal pain and/or dyspnea, while one patient (Case 1) received elective DH reduction after a 3-month period of intermittent anorexia and nausea. Abdominal contents, the jejunum and/or the transverse colon, had herniated into the right thoracic cavity (*n* = 1) or the left thoracic cavity (*n* = 4) (Fig. 2). Hernia reduction had been accomplished by an open approach in four patients and laparoscopically in one. Hernia mesh (Marlex™ mesh [CR Bard, Billerica, Massachusetts, USA]) had been used in the elective operation case. In this subject (Case 1), a defect intraoperatively detected in the right mediastinal pleura had been large and stiff and seemed difficult to close solely with simple sutures, which had inclined us to perform mesh placement. In one patient (Case 5), perforation of the incarcerated colon had seriously contaminated the left pleural space, necessitating partial colectomy and thorough thoracic lavage/drainage

(Fig. 3). With a median follow-up period of 24.1 (5.5–137.6) months after DH reduction, the absence of herniation relapse has been confirmed.

## Literature review

Seven articles, comprised of five case reports [13–17] and two describing original research [18, 19], were identified in addition to our cases, providing comprehensive information on a total of 16 patients with symptomatic DH necessitating surgical reduction. According to two original reports [18, 19], the rate of postoperative DH occurrence in patients undergoing TG was 1.9% (11/568). Demographic data for the patients presented in these seven publications were combined and shown in Table 2.

Median patient age was 61.5 (40–81) years. Six patients with stage I cancer and ten patients with stage II/III cancer had undergone TG. Of the 16 TG operations performed, 14 (87.5%) were laparoscopic. At least six patients (37.5%) had received a crus incision. Time intervals between the TG and subsequent DH reduction ranged from 2 days to 36 months (median, 6.4 months). All DH operations were carried out under emergent conditions (seven open, six laparoscopic). Bowel resection was required in two cases. Information on outcome parameters after DH operation, such as follow-up duration or follow-up rate, were not available in the assorted bibliographies.

In addition to the research articles noted above, Matthews et al. [20] and Andreou et al. [21] retrospectively investigated a cohort with DH following esophagogastric surgery and also included patients developing DH after TG (*n* = 4, the former; *n* = 1, the latter study). However, their analyses were broadly designed to examine patients who had undergone “esophagogastric resection surgery” (125 TG in the former study) and did not focus specifically on TG, with neither study providing detailed information on TG-related factors and outcomes.

## Discussion

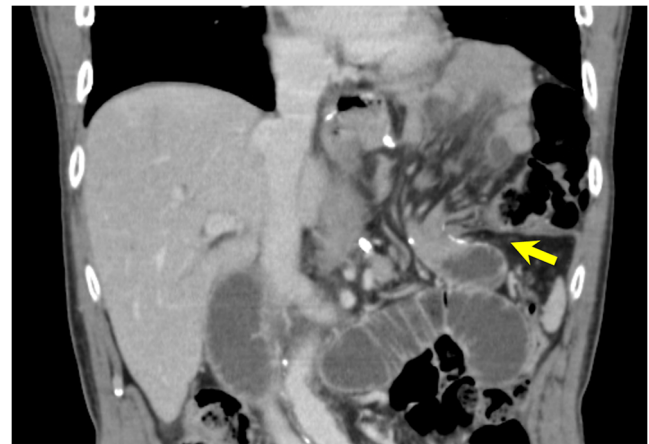
We retrospectively evaluated clinicopathological features of five cases developing DH after TG for gastric or esophagogastric junction cancer and also reviewed prior publications. Despite a comprehensive literature search, only 21 cases (analyzable *n* = 16) who had undergone surgery for DH following TG were identified. According to our review, DH can manifest not only as an early-phase complication but also as a late-onset adverse event requiring emergent intervention (Table 2).

**Table 1** Characteristics of our five patients developing diaphragmatic hernia after total gastrectomy and undergoing surgical repair

Case	Age*	Sex	DH reduction											
			Approach	Reconstruction	Anastomosis	Tumor location	Crus incision	TNM classification	Time interval†	Site	Herniated content	Approach	Bowel resection	Mesh repair
1	64	M	Open (LTA)	Jl (retrocolic)	CS	EGJ	Yes	T3N2M0	189.0 mo (elective)	Right thorax	Jejunum	Open	No	Yes
2	72	M	Open (LTA)	RY (retrocolic)	CS	Cardia	Yes	T3N0M0	78.1 mo (emergent)	Left thorax	Jejunum	Open	No	No
3	72	M	Open	RY (retrocolic)	CS (OrVii™)	EGJ	Yes	T2N3M0	2.9 mo (emergent)	Left thorax	TC	Open	No	No
4	65	M	Laparoscopic	RY (antecolic)	Overlap	Cardia	Yes	T1aN0M0	8.5 mo (emergent)	Left thorax	Jejunum TC	Open	No	No
5	68	F	Laparoscopic	RY (antecolic)	Overlap	Corpus	Yes	T1aN0M0	112.6 mo (emergent)	Left thorax	TC	Laparoscopic	Yes	No

\*at DH reduction † between prior TG and DH reduction

TG total gastrectomy, DH diaphragmatic hernia, M male, F female, LTA left thoracoabdominal, JI jejunal interposition, RY Roux-en-Y, CS circular stapling, EGJ esophagogastric junction, TC transverse colon



**Fig. 2** Coronal section from a contrast-enhanced computed tomographic scan showing herniation of the bowels (jejunum and transverse colon) into the left pleural cavity (Case 4). Arrow indicates the hernial orifice

Our analysis of data from a period of nearly three decades revealed that DH can occur suddenly several years (~ 16 years at maximum) after TG (Table 1). This observation shows that patients undergoing TG are at persistent risk of DH occurrence even well after the standard 5-year follow-up surveillance period and that the incidence of DH after TG might thus have been underestimated in conventional retrospective studies including ours.

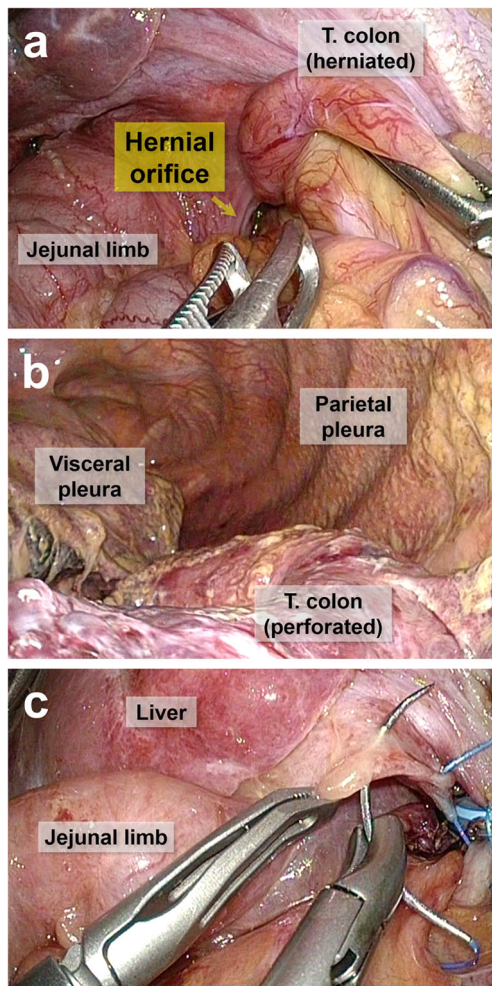
Our results may suggest predictive factors for DH occurrence after TG. First, the incidence of postoperative DH was markedly higher with laparoscopic TG (3.4%) than with open TG (0.2%). Our literature review also showed more patients to develop DH after laparoscopic TG than after open TG (Table 2). Several previous studies have highlighted decreased intraabdominal adhesions after laparoscopic gastrectomy as being causally related to an increased risk of postoperative internal hernia development [5, 6, 22]. Collectively, the same observations may apply to post-TG herniation through a diaphragmatic orifice. To date, several technological improvements in surgical instruments have enhanced the effectiveness of the laparoscopic approach, and laparoscopic TG is therefore coming into ever more widespread use. Accordingly, the frequency of postoperative internal hernias, including DH, is expected to continue rising.

Incision of the crus during TG was also esteemed in a previous study as a risk factor for postoperative hiatal herniation [18]. This mechanism may reflect a suction effect of the negative intrathoracic pressure leading to progressive dilation of the damaged crus. In the current study, indeed, crus incision had been performed in all five cases with postoperative DH. Based on these findings, tight closure and appropriate fixation of the intraabdominal defects including the incised diaphragmatic crus are, especially in laparoscopic TG, strongly recommended. In respect of prophylaxis against DH, the value of mesh placement or other optimized fixation is still uncertain due to lack of



supporting evidence, though some studies suggested mesh repair was a good method to cover an intracorporeal orifice without unfavorable tension [13, 19, 20].

The limitations of our study include its retrospective design. The relatively small number of DH cases, even with the addition of published cases, and absence of control groups for a comparative analysis are inherent limitations of our study. However, we hope that our long-term observations of the rare entity of DH after TG will spur future research focusing in this area, especially in the current era of ever more widespread use of laparoscopic procedures. Further study with a larger sample size is necessary to draw a definitive conclusion and provide surgical guidelines for preventing the life-threatening development of DH after TG.



**Fig. 3** Intraoperative view of laparoscopic repair of postgastrectomy diaphragmatic hernia (Case 5). **(a)** The transverse colon was incarcerated into the left thorax via a diaphragmatic defect (*arrow*). **(b)** The incarcerated colon had become perforated in the thoracic cavity, causing serious contamination of the pleural space. **(c)** The herniated colon with the perforation site was extracted and moved back into the abdomen, followed by resection of the necrotic portion. After extensive lavage and drainage, the orifice was closed using an intracorporeal continuous barbed suture of nonabsorbable V-Loc™ (Covidien, Dublin, Ireland)

**Table 2** Clinical characteristics of the 16 patients with symptomatic diaphragmatic hernia from the published literature

Variables	
Age (median)	40–81 (61.5)
Sex*	
Male	7 (43.75%)
Female	6 (37.5%)
<i>Prior total gastrectomy</i>	
Approach	
Open	2 (12.5%)
Laparoscopic	14 (87.5%)
Crus incision*	
Yes	6 (37.5%)
Pathological stage	
I	6 (37.5%)
II	4 (25%)
III	6 (37.5%)
<i>Diaphragmatic hernia reduction</i>	
Time interval from total gastrectomy (median)	2 days–36 months (6.4 months)
Main complaint*	
Abdominal pain	10 (62.5%)
Emesis	3 (18.75%)
Dyspnea	2 (12.5%)
Procedure	
Elective	0 (0%)
Emergent	16 (100%)
Approach*	
Open	7 (43.75%)
Laparoscopic	6 (37.5%)
Bowel resection*	
Yes	2 (12.5%)
No	11 (68.75%)
Mesh repair*	
Yes	2 (12.5%)
No	11 (68.75%)

\*With regard to remaining cases, detailed information was lacking in these reports.

## Conclusion

Though the occurrence of DH in the context of TG is rare, this risk may persist for many years after the operation, and it would likely present as a very late-onset complication requiring emergent management. The laparoscopic approach was strongly suggested to be a predictive factor for DH development following TG. Incising the diaphragmatic crus may also be a risk indicator for DH after TG. To prevent postoperative DH, measures such as appropriate closure of the crus would be recommended in minimally invasive TG.

**Authors' contributions** M. Urabe and S. Haruta participated in study conception and design, acquisition of data, analysis and interpretation of data, and drafting of manuscript; Y. Ohkura participated in acquisition data, analysis and interpretation of data, and drafting of manuscript; and M. Ueno and H. Udagawa participated in acquisition of data, drafting of manuscript, and critical revision of manuscript.

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## Compliance with ethical standards

**Disclosures of ethical statements** The institutional review board of Toranomon Hospital approved the research protocol.

**Conflict of interest** The authors declare that they have no conflicts of interest.

**Ethics approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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