Surg Endosc (2016) 30:5419–5427
DOI 10.1007/s00464-016-4899-5

# Diaphragmatic herniation following esophagogastric resectional surgery: an increasing problem with minimally invasive techniques?

## Post-operative diaphragmatic hernias

**Jacob Matthews[1] · Shivam Bhanderi[1] · Harriet Mitchell[2] · John Whiting[1] · Ravinder Vohra[3] · James Hodson[4] · Ewen Griffiths[1,5]**

Received: 20 January 2016 / Accepted: 26 March 2016 / Published online: 22 April 2016


**Abstract**
*Background* Post-operative diaphragmatic hernias (PODHs) are serious complications following esophagectomy or total gastrectomy. The aim of this study was to describe and compare the incidence of PODHs at a high volume center over time and analyze the outcomes of patients who develop a PODH.
*Methods* A prospective database of all resectional esophagogastric operations performed for cancer between January 2001 and December 2015 was analyzed. Patients diagnosed with PODH were identified and data extracted regarding demographics, details of initial resection, pathology, PODH symptoms, diagnosis and treatment.
*Results* Out of 631 patients who had hiatal dissection for malignancy, 35 patients developed of PODH (5.5 % overall incidence). Median age was 66 (range 23–87) years. The incidence of PODH in each operation type was: 2 % (4/221) following an open 2 or 3 stage esophagectomy, 10 % (22/212) following laparoscopic hybrid esophagectomy, 7 % (5/73) following MIO, and 3 % (4/125) following total gastrectomy. The majority of patients had colon or small bowel in a left-sided hernia. Of the 35 patients who developed a PODH, 20 (57 %) patients required emergency surgery, whereas 15 (43 %) had non-urgent repair. The majority of the patients had had suture repair ($n = 24$) or mesh repair ($n = 7$) of the diaphragmatic defect. Four patients were treated non-operatively. In hospital post-operative mortality was 20 % (4/20) in the emergency group and 0 % (0/15) in the elective group. Further hernia recurrence affected seven patients ($n = 7/27$, 26 %) and 4 of these patients (15 %) presented with multiple recurrences.
*Conclusion* PODH is a common complication following hybrid esophagectomy and MIO. Given the high mortality from emergency repair, careful thought is needed to identify surgical techniques to prevent PODH forming when minimal access esophagectomy are performed. Upper GI surgeons need to have a low index of suspicion to investigate and treat patients for this complication.

**Keywords** Esophagectomy · Minimally invasive surgery · Diaphragmatic hernia

Over the past 5–10 years there have been increasing numbers of laparoscopic-assisted or minimally invasive

**Declaration** Preliminary data from this study were presented at Digestive Diseases Foundation, London, June 2015 and an abstract was published in Gut: *PWE-156 Post-esophagectomy diaphragmatic hernias: an increasing problem with the move to minimally invasive esophagectomy. Gut 64 (Suppl 1):A281; June 2015* and was presented at the Association of Laparoscopic Surgeons GB&I meeting 27th November 2015, Southport, England, and an abstract due to be published in *Surgical Endoscopy*.

✉ Ewen Griffiths
Ewen.Griffiths@uhb.nhs.uk

[1] Department of Upper Gastrointestinal Surgery, University Hospitals Birmingham NHS Foundation Trust, Birmingham, UK

[2] Faculty of Medicine and Dentistry, University of Bristol, Bristol, UK

[3] Nottingham Oesophago-Gastric Unit, Nottingham University Hospitals NHS Foundation Trust, Hucknall Road, Nottingham, UK

[4] Institute of Translational Medicine, University Hospitals Birmingham NHS Foundation Trust, Birmingham, UK

[5] Department of Upper Gastrointestinal Surgery, Area 6, 7th Floor, Queen Elizabeth Hospital Birmingham, Mindelsohn Way, Edgbaston, Birmingham B15 2WB, UK

esophagectomies (MIO) performed [1]. Advantages of minimal access approaches to the esophagus include a lower risk of postoperative chest infection, shorter length of stay, quicker return to work and post-operative recovery [2–4]. There are cited disadvantages, including higher rates of gastric conduit necrosis and anastomotic leak [5, 6]. In addition, there are increasing reports of diaphragmatic herniation following esophagectomy performed using minimally invasive techniques [7, 8].

The incidence of post-operative diaphragmatic hernia (PODH) after esophagectomy is estimated to be between 0.7 and 15 % [9]. The rate varies depending on the operative technique used for esophageal resection, whether only symptomatic patients were included, duration and imaging follow-up protocol and how rigorously small hernias are looked for in post-operative imaging. PODH can also occur after total gastrectomy, especially when extensive hiatal dissection is performed. The incidence of PODH after total gastrectomy has not been accurately described. Herniation of the abdominal viscera into the thorax can result in severe respiratory compromise and intestinal ischemia with perforation. PODH can occur early in the post-operative period or after several years. It is unclear if there are differences in the rate of PODH between open operations versus hybrid (laparoscopic gastric dissection and an open thoracic phase) operations versus MIO.

The aim of this study was to describe and compare the incidence of PODH over time and analyze the outcomes of patients who develop such a complication using a prospectively collected database of esophagogastric cancer resections from a single tertiary center.

## Materials and methods

A departmental database containing prospectively collected patient data to track the management of patients with esophagogastric cancer was used to obtain data of all consecutive patients undergoing resectional surgery between January 2001 and December 2014. Study approval was obtained from the University Hospitals Birmingham NHS Foundation Trust, Audit Department (CARMS-00103).

### Inclusion and exclusion criteria

All consecutive patients undergoing esophagectomy or total gastrectomy for malignant disease were included. Esophagectomies were classified as: (1) open 2 or 3 stage procedures involving open abdominal incisions (midline or roof top incisions) with open right thoracotomy, (2) laparoscopic abdominal gastric mobilization (5 port technique) with an open right thoracotomy (hybrid esophagectomy) plus or minus cervical incision, or (3) MIO with (5 port abdominal ports) and thoracoscopic (3 thoracic ports) esophageal mobilization with either intrathoracic or cervical anastomosis. The decision regarding operative method (open or minimally invasive) was at the discretion of the Consultant Surgeon involved. Ten Consultant Upper Gastrointestinal Surgeons were involved in oesophagogastric cancer resections throughout the study period. Although operative methods evolved in the time period of the study, no suturing was ever performed from the gastric conduit to the diaphragmatic crus in any of the operative procedures. Before 2006 all procedures were open operations. The first laparoscopic gastric mobilization was performed in the unit in 2006 and fully minimally invasive procedures introduced in 2008. Patients undergoing resectional surgery without hiatal dissection and surgery for benign diseases were excluded. Trans-hiatal esophagectomies were also excluded, as only small numbers are performed in the Unit (none of these patients developed PODH, data not shown).

### Primary outcome

PODH was defined as thoracic herniation of any abdominal organ or viscus other than a normally placed gastric pull-up or roux-en-y limb following esophagectomy or total gastrectomy, respectively [10, 11].

### Data validation and completeness

To ensure all patients with diaphragmatic hernia who had operative intervention were included, a search of Hospital Episode Statistics was performed using the ICD-10 code K44 (diaphragmatic hernia) and OPCS-4 code for repairs of diaphragmatic hernias (G23.1—Transthoracic repair of para-esophageal hiatus hernia, G23.2—Transthoracic repair of diaphragmatic hernia (acquired), G23.3—Transabdominal repair of hiatus hernia, G23.4—Transabdominal repair of diaphragmatic hernia, G23.8—Other specified repair of diaphragmatic hernia, G23.9—Unspecified repair of diaphragmatic hernia). This also ensured patients diagnosed or treated at other hospitals were not missed [12]. Missing data were retrospectively collected using online patient records, imaging reports and patient case notes. Routine postoperative CT imaging was not performed in our unit unless patients became symptomatic.

### Other variables and statistical analysis

Data were collected on demographics, final histopathology, radiological investigations, operative repair and all post-operative complications for both the index operation and the repair of the PODH. Presenting symptoms of hernia,

technique of surgical repair (e.g., suture or mesh), length of stay and post-operative mortality were also recorded.

Statistical analysis was performed using Fisher's exact test for nominal variables, Kendall's tau for ordinal variables, and Mann–Whitney tests for continuous variables. A multivariable binary logistic regression model was then performed, in order to identify independent predictors of PODH. Variables with categories that had no cases of PODH were categorized, prior to this analysis, in order to make the model calculable. A forwards stepwise entry method was used to select the best predictors of PODH.

All analyses were performed using IBM SPSS 22 (IBM Corp. Armonk, NY), with $p < 0.05$ deemed to be indicative of statistical significant throughout.

## Results

A total of 824 resectional operations were performed between January 2001 and December 2015 and included in the departmental database. After the exclusion of 193 patients for a variety of reasons, 631 patients who had a hiatal dissection during their resectional operation were analyzed (Fig. 1). A total of 506 transthoracic esophagectomies (221 open, 212 hybrid, 73 MIO) and 125 total gastrectomies (5 laparoscopic assisted) were performed during this time period.

The 631 patients (484 males, 147 females) included in the study were followed up for a median of 19 months (IQR 9–43 months). During this period, 35 patients (31 males, 4 females) developed PODH (5.5 % incidence; Table 1). The incidence of PODH in each operation type was: 1.8 % (4/221) following an open 2 or 3 stage esophagectomy, 10.4 % (22/212) following laparoscopic hybrid esophagectomy, 6.8 % (5/73) following MIO, and 3.2 % (4/125) following laparoscopic or open total gastrectomy (Fig. 2). The incidence of PODH appears to have changed with time, especially after the introduction of laparoscopic techniques in 2006 (Fig. 2).

Of the 35 cases of PODH, 27 patients (77 %) had surgery for lower esophageal or gastro-esophageal junctional adenocarcinoma (Siewert type 1 or 2), 6 patients (17 %) for middle or lower third squamous cell carcinoma and 2 (6 %) for cardia (Siewert type 3) adenocarcinoma. Two patients were found to have giant hiatus hernias during their index operations (1 MIO, 1 Hybrid). Median age was 64 (range 42–81) years (Table 1). PODH rates were found to differ significantly by the type of operation ($p < 0.001$), with the highest rate in hybrid esophagectomy (10 %), and the lowest in open esophagectomy (2 %). PODH rates were also found to increase significantly by year of surgery ($p = 0.015$), with none of the 93 operations in 2000–2003 resulting in PODH, compared to 7 % in 2012–2014. T stage was a significant predictor of PODH ($p = 0.045$),

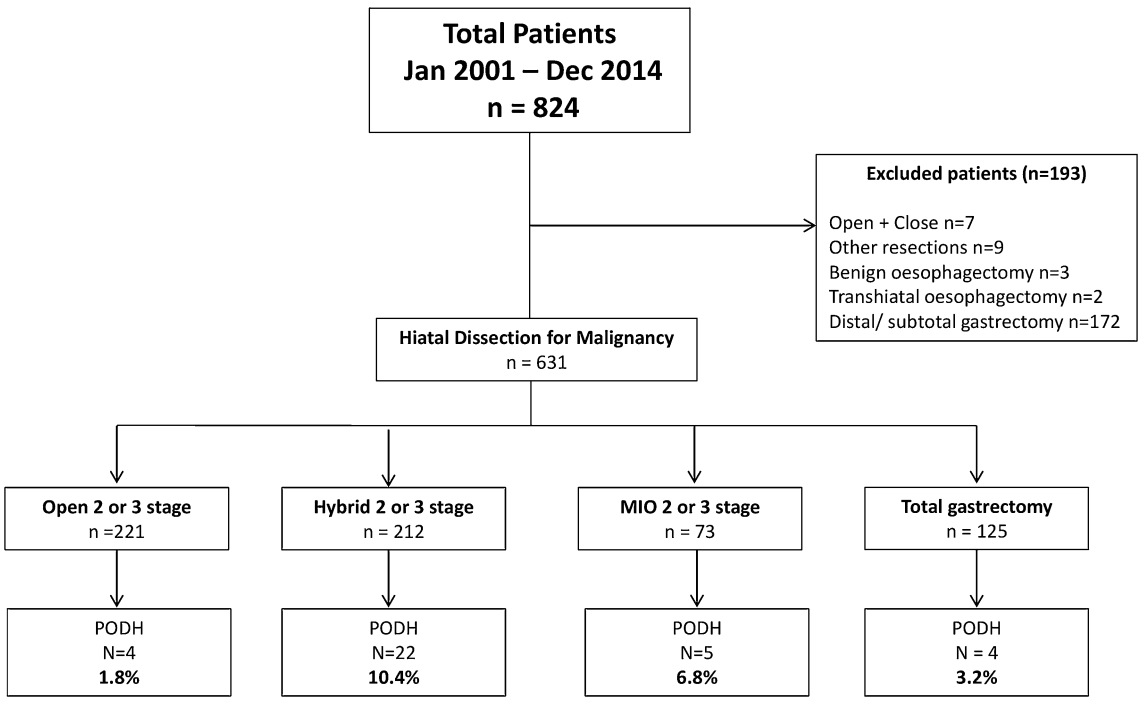


**Fig. 1** Consort diagram showing all the patients included in the study and the rate of diaphragmatic herniation in each group (Open, Hybrid, MIO and Total Gastrectomy)

**Table 1** Comparison between patients with and without PODH

| | *N* | No PODH | PODH | *p* value |
|---|---|---|---|---|
| Age (median, range) | 631 | 66 (23–87) | 64 (42–81) | 0.186 |
| Sex[a] | | | | 0.101 |
| Female | 147 | 143 (97.3 %) | 4 (2.7 %) | |
| Male | 484 | 453 (93.6 %) | 31 (6.4 %) | |
| Operation[a] | | | | <0.001* |
| Open esophagectomy | 221 | 217 (98.2 %) | 4 (1.8 %) | |
| Hybrid esophagectomy | 212 | 190 (89.6 %) | 22 (10.4 %) | |
| Full MIO | 73 | 68 (93.2 %) | 5 (6.8 %) | |
| Total gastrectomy | 125 | 121 (96.8 %) | 4 (3.2 %) | |
| Year of operation | | | | 0.015* |
| 2000–2003 | 93 | 93 (100.0 %) | 0 (0.0 %) | |
| 2004–2007 | 173 | 165 (95.4 %) | 8 (4.6 %) | |
| 2008–2011 | 185 | 171 (92.4 %) | 14 (7.6 %) | |
| 2012–2014 | 180 | 167 (92.8 %) | 13 (7.2 %) | |
| Histology[a] | | | | 0.403 |
| Adeno | 492 | 463 (94.1 %) | 29 (5.9 %) | |
| SCC | 103 | 97 (94.2 %) | 6 (5.8 %) | |
| Other | 36 | 36 (100.0 %) | 0 (0.0 %) | |
| T stage | | | | 0.045* |
| T0 | 37 | 37 (100.0 %) | 0 (0.0 %) | |
| T1 | 80 | 77 (96.3 %) | 3 (3.8 %) | |
| T2 | 119 | 113 (95.0 %) | 6 (5.0 %) | |
| T3 | 355 | 333 (93.8 %) | 22 (6.2 %) | |
| T4 | 35 | 31 (88.6 %) | 4 (11.4 %) | |
| N stage | | | | 0.931 |
| N0 | 243 | 232 (95.5 %) | 11 (4.5 %) | |
| N1 | 141 | 131 (92.9 %) | 10 (7.1 %) | |
| N2 | 129 | 118 (91.5 %) | 11 (8.5 %) | |
| N3 | 118 | 115 (97.5 %) | 3 (2.5 %) | |
| M stage | | | | 0.226 |
| M0 | 605 | 572 (94.5 %) | 33 (5.5 %) | |
| M1 | 16 | 14 (87.5 %) | 2 (12.5 %) | |

*p* values from Mann–Whitney tests for continuous variables, or Kendall's tau for categorical variables, unless stated otherwise

* Significant at $p < 0.05$

[a] *p* value from Fisher's exact test

with no cases in the 37 T0 patients, compared to an 11 % PODH rate in T4. None of the other factors considered were found to be significantly associated with PODH (Table 1). A multivariable analysis was performed, which found the type of operation to be the only significant independent predictor of PODH.

Of the 35 patients who developed a PODH, 20 (57 %) patients presented acutely and required emergency surgery (Table 2). Fifteen (43 %) patients were diagnosed from the outpatient clinic and had planned surgical intervention or watchful waiting. Common presenting symptoms were shortness of breath, chest or abdominal pain, and vomiting. Diagnosis of a PODH was made after a CT scan ($n = 30$), plain X-ray ($n = 4$) and one patient was diagnosed at laparotomy. The majority of patients had a PODH affecting their left chest (97 %) and had either colon ($n = 18$, 51 %), small bowel ($n = 4$, 11 %) or both ($n = 12$, 34 %) in the hernia (Table 2). Six patients (17 %) developed PODH within 7 days of their index surgery, a further 6 patients (17 %) between 7 and 90 days, 10 patients (29 %) between 90 days and 1 year, another 6 patients (17 %) between 1 and 2 years; 2 patients (6 %) between 2 and 3 years and 5 patients presented over 5 years (14 %) from their original surgery (Fig. 3).

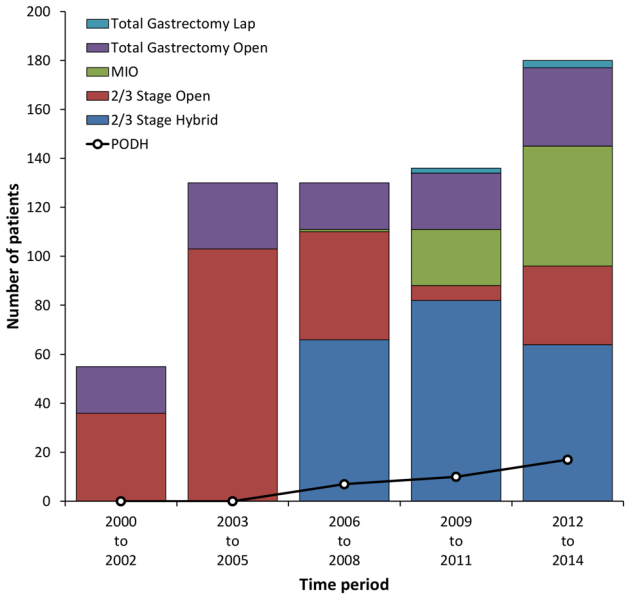


**Fig. 2** The incidence of post-operative diaphragmatic herniation over time with different types of resectional upper gastrointestinal surgery

Four patients have not received an operation. One patient had an asymptomatic PODH with colon in the left chest, and he continues to be followed up on a regular basis in the surgical clinic. Two patients had evidence of metastatic disease and were therefore treated conservatively. One further patient had small bowel in the left chest following radical total gastrectomy. He was treated conservatively as he was not fit for operative repair, due to the development of a second primary head and neck tumor and poor patient fitness.

Of the 31 patients who had surgery for PODH, the operative methods used were suture repair ($n = 24$) or mesh repair ($n = 7$) of the diaphragmatic defect. Laparoscopic views of patients having suture and mesh repairs are shown in Figs. 4, 5, respectively. Mesh types used were Parietex TM composite dual layer mesh (Covidien Ltd, Dublin, Republic of Ireland; $n = 5$), polypropylene mesh ($n = 1$) and Surgisis biological mesh (Biodesign™ Surgisis® Graft, Cook Medical, Bloomington, USA) ($n = 1$). In 12 cases the repair of the defect was planned as an open procedure from the start. In 19 cases repair was attempted laparoscopically but in 8 of these patients (42 %) conversion to open surgery was required for a variety of reasons. These included the requirement for bowel resections (colon $n = 2$, small bowel $n = 1$), resection of infarcted omentum ($n = 2$), and splenectomy due to bleeding from iatrogenic injury ($n = 1$). In the other two cases, the operation could not proceed laparoscopically due to inability to reduce the contents of the hernia and failure to progress.

The overall median length of stay following the PODH repair was 13 days (range 3–48 days); but shorter when successfully treated laparoscopically (median = 7 days, range 3–36 days). The median length of stay for non-emergency cases was 6.3 days (range 3–48 days) compared to 17 days for emergency cases (range 7–36 days). Those repairs that required conversion on average stayed for 19 days (range 12–48 days).

**Table 2** Presenting features, details and methods of surgical repair in those patients who were diagnosed with a PODH ($n = 35$)

| Characteristic | *N* (%) |
|---|---|
| Presentation | |
| Non-emergency | 15 (43) |
| Emergency | 20 (57) |
| Symptoms | |
| Shortness of breath | 14 (40) |
| Chest pain | 7 (20) |
| Abdominal pain | 13 (37) |
| Vomiting | 14 (40) |
| Dysphagia | 4 (11) |
| Constipation | 7 (20) |
| Diarrhea | 1 (3) |
| Diagnostic imaging | |
| Clinical | 1 (3) |
| CXR | 4 (11) |
| CT | 6 (17) |
| CXR + CT | 24 (69) |
| Side of chest | |
| Left | 34 (97) |
| Right | 1 (3) |
| Contents of hernia | |
| Colon | 30 (86) |
| Small bowel | 16 (46) |
| Omentum | 3 (9) |
| Pancreas | 1 (3) |
| Distal stomach | 1 (3) |
| Spleen | 1 (3) |
| Repair method | |
| Not performed | 4 (11) |
| Suture repair | 24 (69) |
| Mesh repair | 7 (20) |
| Operation method[a] | |
| Open | 12 (39) |
| Laparoscopic | 11 (35) |
| Converted to open | 8 (26) |
| Hernia recurrence[b] | |
| No | 20 (74) |
| Yes | 7 (26) |

[a] For the 31 patients where a hernia repair was performed

[b] Excluding patients who did not have surgery or who died post-operatively

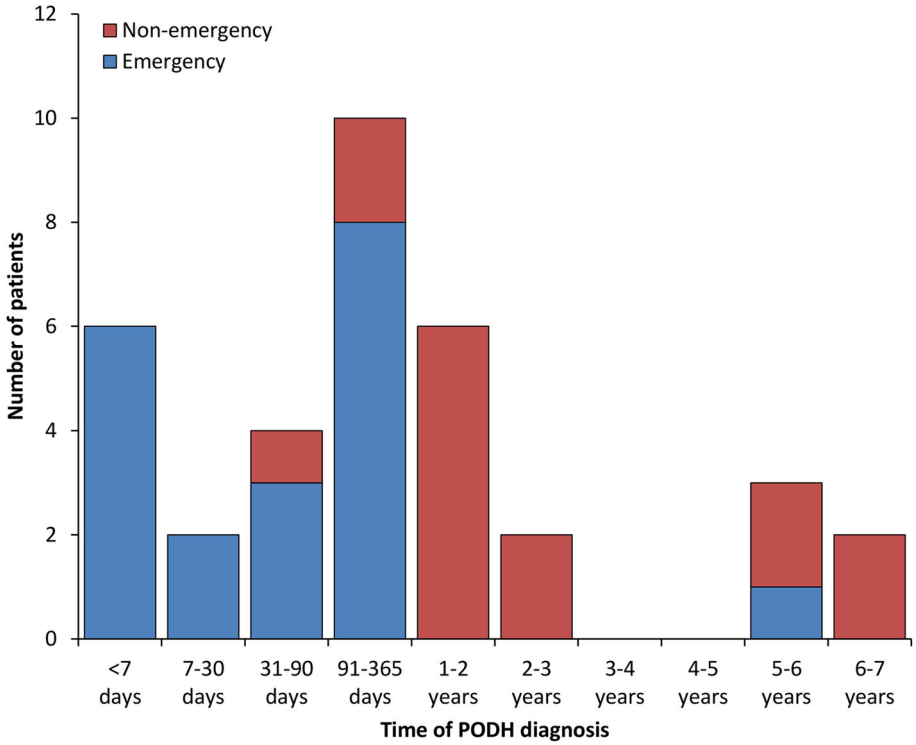


**Fig. 3** The timing of the diagnosis of PODH. Emergency and non-emergency presentations are shown

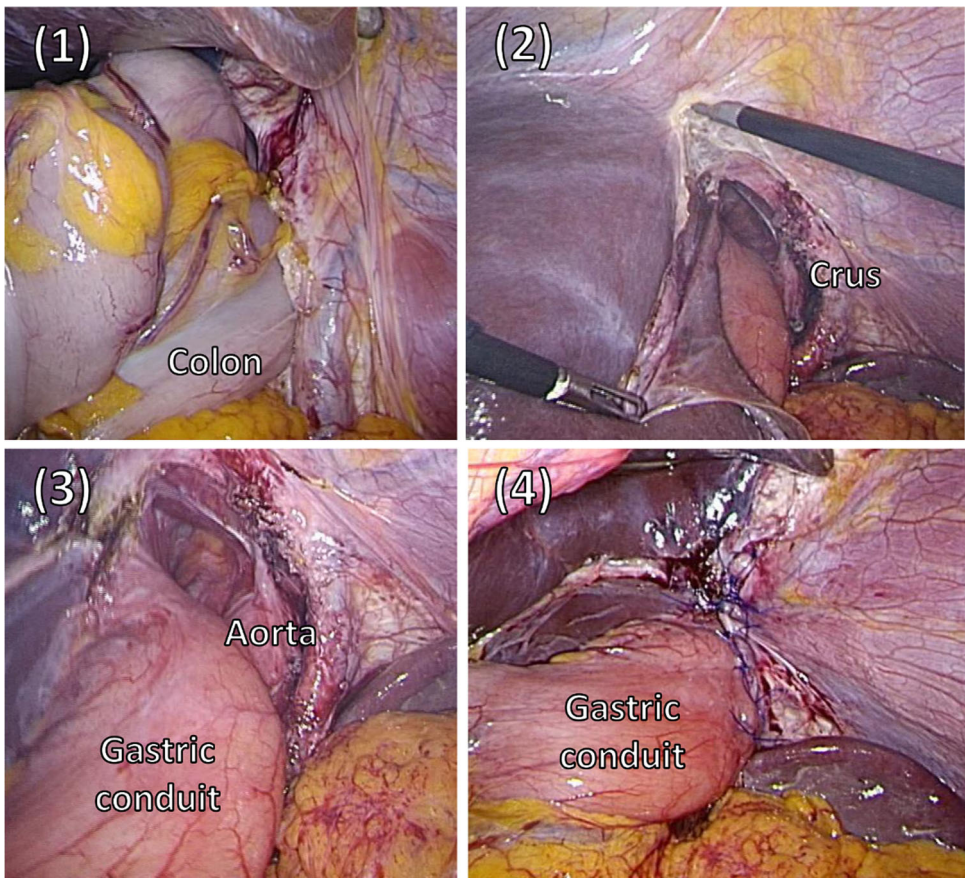


**Fig. 4** Laparoscopic appearance of a PODH in a patient who had a minimally invasive esophagectomy. The colon can be observed entering the hernia (**1**). After the colon is reduced, the left lobe of the liver is mobilized to free the diaphragm anteriorly (**2**). The view after reduction shows the gastric conduit and the aorta (**3**). The hernia is repaired with permanent sutures (2/0 Prolene), and the diaphragm is closed anteriorly and the left crus is sutured to the gastric conduit (**4**)

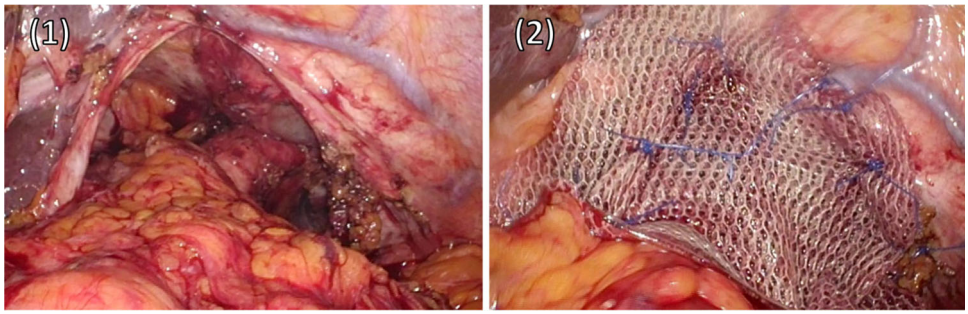


**Fig. 5** Laparoscopic appearance of a large PODH in a patient who had a minimally invasive esophagectomy showing wide diaphragmatic crura (**1**) and repair with a dual layer Mesh (**2**)

In hospital post-operative mortality was 13 % ($n = 4/31$). All of the mortalities occurred in patients who required emergency surgery ($n = 4/20$, 20 %). One of these patients died after colonic bowel ischemia and perforation caused fecal contamination of the left chest. Despite treatment with damage control surgery and ITU support, they unfortunately developed multi-organ failure and died. Two patients died of severe pneumonia and multi-organ failure after emergency repairs. Another patient died on ITU after cardiorespiratory arrest.

After the exclusion of patients who died after surgery, further hernia recurrence affected seven patients (25.9 %), with four patients (14.8 %) having multiple recurrences. The majority of these (5/7) had initial suture repairs, and the remainder had mesh repairs. None of the patients who had diaphragmatic hernias repaired after total gastrectomy had any recurrence ($n = 0/4$).

## Discussion

This prospective cohort study performed over 13 years included 631 patients at risk of PODH. It demonstrates that, since the introduction of laparoscopic abdominal approaches and MIO, there has been an associated increase in the rate of PODH. PODH is not an uncommon complication and the majority of patients present with respiratory distress and occasionally signs of bowel ischemia requiring emergency surgery. These can be treated via an open repair or laparoscopically, but it should be realized that conversion to open procedures and recurrence is high.

There are many theories why the rates of PODH are increasing. Possible hypotheses include reduction in intra-abdominal adhesions with laparoscopic surgery [7]. We found that PODH rates were highest in hybrid operations (10.4 %) and MIO procedures (6.8 %), perhaps going against this hypothesis. However, hybrid operations were started earlier in the series and patients have had more time to develop PODH. In addition, in the face of patients presenting with PODH with minimal access techniques we began to modify our technique and perform a suture colopexy in attempt to limit transverse colon herniation. Increasing intra-abdominal pressure with early mobilization as part of an enhanced recovery program could be another factor. Other studies have suggested the BMI of patients, or pre-existing hiatal hernia and radical surgical resection of the diaphragmatic crura are risk factors. Another recent study suggested the increasing incidence is due to improved survival due to neo-adjuvant oncological therapies [13].

Our results are similar to another UK series published recently [11]. Messenger et al. reported a higher rate after hybrid esophagectomy (12 % 8/67) and full MIO (17 % 1/6); however, this was based on a smaller series than in our study. Interestingly, in this study, no patients with an open two stage (0/144) or three stage procedures (0/19) develop PODH, but reported a rate of 5 % (2/42) with transhiatal resectional procedures. Our unit performed only two transhiatal esophagectomies and neither of these patients developed PODH. Other series have reported rates of PODH between 0.84 and 5 % in transhiatal esophagectomies [9, 14]. Theories for the risk in this procedure include the need for widening of the hiatus to allow insertion of the surgeon's hand transhiatally to aid in the blunt dissection.

PODHs after total gastrectomy are under-reported in the current literature and are said to be rare occurrences. However, we found a rate of 3.2 % (4/125) following laparoscopic or open total gastrectomy. This is in contrast to a large series from Japan which suggested that it only affected 0.01 % of their patients having gastrectomy for cancer [10]. However, it could be that a typical Japanese patient is thinner with a lower BMI and has less risk of a PODH [15].

There are limitations to this study in that the data were retrospectively collected for the details of the PODH treatment. In the series presented here, patients did not have routine postoperative CT imaging to detect recurrence, so the incidence of PODH may be higher. However, the value of detecting and treating small asymptomatic PODH is currently unproven. Due to the low incidence rate of symptomatic PODH, analyses comparing the two groups

of patients were of low statistical power. A post hoc power calculation estimated a threefold difference between groups to be the minimal detectable difference in the analysis (at 80 % power). Hence, the false negative rate for analyses was high, meaning that clinically relevant differences between groups may have been missed. Nevertheless, we used a large prospective database of cancer resections performed in one high volume center and ensured case ascertainment through accurate interrogation of national informatics data.

Several techniques have been described to reduce the incidence of PODH following hybrid approaches and MIO, but little data are available on their efficacy. Avoiding unnecessary division of the diaphragmatic muscle is important, but sometimes is unavoidable. Following a trans-hiatal esophagectomy, a large diaphragmatic defect may be closed, while the abdomen is still open; either by suturing the crural defect or suturing the gastric conduit to the diaphragmatic edge [14]. Other surgeons advocate the use of a biological mesh to close the hiatus to prevent this problem [16]. If these techniques are employed, it is important not to compromise the blood supply to the gastric conduit. However, these techniques are not easily applicable to two stage trans-thoracic esophagectomy, unless the abdomen is entered for a second time after the thoracic procedure is completed [17]. Wells et al. describe the placement of permanent sutures around a lax diaphragmatic crura at the time of the abdominal phase of laparoscopic gastric mobilization [18]. These are passed through into the chest and only tied later in the thoracic procedure when the gastric conduit is in its transthoracic position. The authors feel this technique avoids the difficulty in closing the defect via a thoracotomy and also avoids difficulty in delivering the conduit should it be narrowed first. Other surgeons, recognizing that colon is frequently found in a PODH, have described the suturing of the transverse colon to the abdominal wall as colopexy to potentially prevent PODH [19]. Without larger series, it is not clear which of these techniques is superior; however, our unit has now adopted a routine colopexy with permanent suture in minimally invasive and hybrid esophagectomy.

## Conclusion

PODH is a common complication following hybrid esophagectomy and MIO. One hypothesis is there are fewer intra-abdominal adhesions formed when minimal access techniques are used. Careful thought is needed to identify surgical techniques to prevent PODH forming when minimal access esophagectomy are performed. Upper GI surgeons need to have a low index of suspicion to investigate and operate on these patients for this complication as emergency surgery has a high mortality and poor outcome.

**Acknowledgments** We would like to thank all the Consultant Upper Gastrointestinal Surgeons from UHB for allowing their patients to be included in the study. We also thank the Department of Medical Informatics for providing data and Medical Records for obtaining case notes.

**Disclosures** Jacob Matthews, Shivam Bhanderi, Harriet Mitchell, John Whiting, Ravinder Vohra, James Hodson and Ewen Griffiths have no conflicts of interest or financial ties to declare. This study was completed with funding from the Queen Elizabeth Hospital Birmingham Charity (Upper Gastrointestinal Fund) and the Upper GI Blues Charity, Sandwell.

## References

1. Chadwick G, Taylor A, Groene O, Cromwell D, Hardwick R, Riley S, Crosby T, Greenaway K (2014) National OesophagoGastric Cancer Audit 2014. 57. The Healthcare Quality Improvement Partnership (HQIP). http://www.hscic.gov.uk/catalogue/PUB16020/clin-audi-supp-prog-oeso-gast-2014-rep.pdf. Accessed 17 Dec 2015
2. Zhou C, Zhang L, Wang H, Ma X, Shi B, Chen W, He J, Wang K, Liu P, Ren Y (2015) Superiority of minimally invasive oesophagectomy in reducing in-hospital mortality of patients with resectable oesophageal cancer: a meta-analysis. PLoS One 10:e0132889. doi:10.1371/journal.pone.0132889
3. Nagpal K, Ahmed K, Vats A, Yakoub D, James D, Ashrafian H, Darzi A, Moorthy K, Athanasiou T (2010) Is minimally invasive surgery beneficial in the management of esophageal cancer? A meta-analysis. Surg Endosc 24:1621–1629. doi:10.1007/s00464-009-0822-7
4. Luketich JD, Alvelo-Rivera M, Buenaventura PO, Christie NA, McCaughan JS, Litle VR, Schauer PR, Close JM, Fernando HC (2003) Minimally invasive esophagectomy. Ann Surg 238:486–495. doi:10.1097/01.sla.0000089858.40725.68
5. Ramage L, Deguara J, Davies A, Hamouda A, Tsigritis K, Forshaw M, Botha A (2013) Gastric tube necrosis following minimally invasive oesophagectomy is a learning curve issue. Ann R Coll Surg Engl 95:329–334. doi:10.1308/003588413X13629960045751
6. Veeramootoo D, Shore AC, Wajed SA (2012) Randomized controlled trial of laparoscopic gastric ischemic conditioning prior to minimally invasive esophagectomy, the LOGIC trial. Surg Endosc 26:1822–1829. doi:10.1007/s00464-011-2123-1
7. Aly A, Watson DI (2004) Diaphragmatic hernia after minimally invasive esophagectomy. Dis Esophagus 17:183–186
8. Fumagalli U, Rosati R, Caputo M, Bona S, Zago M, Lutmann F, Peracchia A (2006) Diaphragmatic acute massive herniation after laparoscopic gastroplasty for esophagectomy. Dis Esophagus 19:40–43
9. Price TN, Allen MS, Nichols FC, Cassivi SD, Wigle DA, Shen KR, Deschamps C (2011) Hiatal hernia after esophagectomy: analysis of 2,182 esophagectomies from a single institution. The Annals of Thorac Surg 92:2041–2045. doi:10.1016/j.athoracsur.2011.08.013
10. Murata S, Yamazaki M, Kosugi C, Hirano A, Yoshimura Y, Shiragami R, Suzuki M, Shuto K, Koda K (2014) Hiatal hernia following total gastrectomy with Roux-en-Y reconstruction. Hernia 18:889–891. doi:10.1007/s10029-013-1142-3
11. Messenger DE, Higgs SM, Dwerryhouse SJ, Hewin DF, Vipond MN, Barr H, Wadley MS (2015) Symptomatic diaphragmatic

herniation following open and minimally invasive oesophagectomy: experience from a UK specialist unit. Surg Endosc 29:417–424. doi:10.1007/s00464-014-3689-1

12. Slavin J, Deakin M, Wilson R (2012) Surgical research and activity analysis using Hospital Episode Statistics. Ann R Coll Surg Engl 94:537–538. doi:10.1308/003588412X13373405385250
13. Ulloa Severino B, Fuks D, Christidis C, Denet C, Gayet B, Perniceni T (2015) Laparoscopic repair of hiatal hernia after minimally invasive esophagectomy. Surg Endosc. doi:10.1007/s00464-015-4299-2
14. Narayanan S, Sanders RL, Herlitz G, Langenfeld J, August DA (2015) Treatment of diaphragmatic hernia occurring after transhiatal esophagectomy. Ann Surg Oncol 22:3681–3686. doi:10.1245/s10434-015-4366-x
15. Miyagaki H, Takiguchi S, Kurokawa Y, Hirao M, Tamura S, Nishida T, Kimura Y, Fujiwara Y, Mori M, Doki Y (2012) Recent trend of internal hernia occurrence after gastrectomy for gastric cancer. World J Surg 36:851–857. doi:10.1007/s00268-012-1479-2
16. Sutherland J, Banerji N, Morphew J, Johnson E, Dunn D (2011) Postoperative incidence of incarcerated hiatal hernia and its prevention after robotic transhiatal esophagectomy. Surg Endosc 25:1526–1530. doi:10.1007/s00464-010-1429-8
17. Kent MS, Luketich JD, Tsai W, Churilla P, Federle M, Landreneau R, Alvelo-Rivera M, Schuchert M (2008) Revisional surgery after esophagectomy: an analysis of 43 patients. Annals Thorac Surg 86:975–983. doi:10.1016/j.athoracsur.2008.04.098
18. Wells J, Pring C, Dexter S (2008) Closure of the crural defect during a two-stage oesophagogastrectomy. Ann R Coll Surg Engl 90:162–163. doi:10.1308/003588408X261852b
19. Bronson NW, Luna RA, Hunter JG, Dolan JP (2014) The incidence of hiatal hernia after minimally invasive esophagectomy. J Gastrointest Surg 18:889–893. doi:10.1007/s11605-014-2481-9