Annals of Surgery

DOI: 10.1097/SLA.0000000000004812

# Routine Esophagograms Following Hiatus Hernia Repair Minimizes Reoperative Morbidity: A Multicenter Comparative Cohort Study

David S. Liu *PhD, FRACS*[1, 2], Melissa Y. Wee *MD* [1], James Grantham *MD* [1], Bee Ong *MD*[1], Stephanie G. Ng *MD*[1], Minh-Son To *MD*[1], Xuanyu Zhou *MD* [1], Tanya Irvine *BSc (Hons)* [1], Tim Bright *MS, FRACS*[1, 3], Sarah K. Thompson *PhD, FRACS*[1, 3], Lachlan Dandie *MBBS, FRACS* [1, 4], Jonathan Shenfine *PhD, FRACS* [1], David I. Watson *PhD, FRACS* [1, 3]

1. Oesophagogastric Surgery Unit, Flinders Medical Centre, Bedford Park, South Australia, 5042, Australia

2. Department of Surgery, Austin Hospital, Heidelberg, Victoria, 3084, Australia

3. Discipline of Surgery, College of Medicine and Public Health, Flinders University, Bedford Park, South Australia, 5042, Australia

4. Upper Gastrointestinal Surgical Unit, Lyell McEwin Hospital, Elizabeth Vale, South Australia, 5112, Australia

**Corresponding author**

Dr. David S Liu

Oesophagogastric Surgery Unit, Flinders Medical Centre, Flinders Drive, Bedford Park, South Australia, 5042, Australia

Phone: +618 8204 5511; Email: liu.davidsh@gmail.com

**Conflicts of interest:** None declared

**Funding**: None declared

**Ethics**: This study was approved by the South Adelaide Local Health Network Human Research Ethics Committee

**Short title:** Esophagograms post hiatus hernia repair

**Mini abstract**

Hiatus hernia repairs are common. Early complications such as re-herniation, esophageal obstruction and perforation, although infrequent, incur significant morbidity. In this large multicenter cohort study, we show that routine postoperative esophagograms enables early recognition of these complications, expedite surgical management, reduce reoperative morbidity, and improve functional outcomes of patients.

**Abstract**

**Objective:** Determine the utility of routine esophagograms following hiatus hernia repair and its impact on patient outcomes.

**Background:** Hiatus hernia repairs are common. Early complications such as re-herniation, esophageal obstruction and perforation, although infrequent, incur significant morbidity. Whether routine postoperative esophagograms enable early recognition of these complications, expedite surgical management, reduce reoperative morbidity, and improve functional outcomes are unclear.

**Methods:** Analysis of a prospectively-maintained database of hiatus hernia repairs in 14 hospitals, and review of esophagograms in this cohort.

**Results:** 1829 hiatus hernias were repaired. Of these, 1571 (85.9%) patients underwent a postoperative esophagogram. Overall, 1 in 48 esophagograms resulted in an early (<14 days) reoperation, which was undertaken in 44 (2.4%) patients. Compared to those without an esophagogram, patients who received this test prior to reoperation (n=37) had a shorter time to diagnosis (2.4 vs. 3.9 days, p=0.041) and treatment (2.4 vs. 4.3 days, p=0.037) of their complications. This was associated with lower rates of open surgery (10.8% vs. 42.9%, p=0.034), gastric resection (0.0% vs. 28.6%, p=0.022), postoperative morbidity (13.5% vs. 85.7%, p<0.001), unplanned intensive care admission (16.2% vs. 85.7%, p<0.001), and decreased length-of-stay (7.3 vs. 18.3 days, p=0.009). Furthermore, we identified less intraoperative and postoperative complications, as well as superior functional outcomes at one-year follow-up in patients who underwent early reoperations for an esophagogram-detected asymptomatic re-herniation than those who needed surgery for late symptomatic recurrences.

**Conclusions:** Postoperative esophagograms decrease the morbidity associated with early and late reoperations, and should be considered for routine use following hiatus hernia surgery.

**Keywords:** hiatus hernia, fundoplication, esophagogram, contrast swallow

**Author contributions**

David S. Liu *PhD, FRACS*: study conception and design, data analysis and interpretation, drafting of article, final approval

Melissa Y. Wee *MD*: study conception and design, data acquisition, drafting of article, final approval

James Grantham *MD*: study conception and design, data acquisition, drafting of article, final approval

Bee Ong *MD*: study conception and design, data acquisition, drafting of article, final approval

Stephanie G. Ng *MD*: study conception and design, data acquisition, drafting of article, final approval

Minh-Son To *MD*: study conception and design, data acquisition, drafting of article, final approval

Xuanyu Zhou *MD*: study conception and design, data acquisition, drafting of article, final approval

Tanya Irvine *BSc (Hons)*: data acquisition, maintenance and interpretation, drafting of article, final approval

Tim Bright *MS, FRACS*: study conception and design, data interpretation, drafting of article, final approval

Sarah K. Thompson *PhD, FRAC:* study conception and design, data interpretation, drafting of article, final approval

Lachlan Dandie *MBBS, FRACS:* study conception and design, data interpretation, drafting of article, final approval

Jonathan Shenfine *PhD, FRACS:* study conception and design, data interpretation, drafting of article, final approval

David I. Watson *PhD, FRACS:* study conception and design, data interpretation, drafting of article, final approval

## Introduction

Laparoscopic hiatus hernia repairs are becoming increasingly common.[1] The outcomes following surgical repair are generally encouraging, with low operative morbidity whilst achieving substantial symptomatic relief of early satiety, dysphagia and reflux.[2] Despite this, early complications such as re-herniation, esophageal obstruction and gastroesophageal perforation occur in a small subset of patients. Their incidence is significantly higher following large hiatus hernia repair than primary anti-reflux surgery.[3] The recognition and treatment of these complications in the early postoperative period is an important determinant of functional outcomes and patient satisfaction in the longer term.[4]

In theory, performing an esophagogram routinely after each hiatus hernia repair should facilitate early diagnosis of operative complications, and inform the need for reintervention. In practice, this approach is controversial and not widely adopted. Some studies have suggested that routine esophagograms increase healthcare cost, extend hospital stay, and do not reliably identify postoperative complications, alter patient management, or predict the need for reintervention.[5-8] In contrast, other authors have argued that early correction of clinically occult complications identified by routine esophagograms may reduce patient morbidity.[3, 9]

To date, the evidence supporting this debate are all derived from retrospective single center case series, which are limited in power, or non-comparative in design. Furthermore, only one study has specifically examined the role of esophagograms following hiatus hernia repair.[8] The other studies are based predominantly on anti-reflux surgery. Moreover, no study has examined the impact of routine esophagograms on patient morbidity and functional outcomes following hiatus hernia repair.

In this study, we analyzed outcomes from a large prospectively maintained multicenter database, to quantify the clinical utility of routine esophagograms following hiatus hernia repair, and to determine how this approach impacts operative and functional outcomes in patients needing early reinterventions.

## Methods

### Study design

Analysis of a prospectively maintained database was performed for consecutive patients who underwent a hiatus hernia repair from 1 January 2000 to 30 September 2020 at eight public (Flinders Medical Centre, Royal Adelaide, Queen Elizabeth, Lyell McEwin, Noarlunga, North East Community, Repatriation General and Whyalla Hospitals) and six private (Ashford, Burnside War Memorial, Flinders Private, St Andrews, Calvary North Adelaide, and Wakefield Hospitals) centers in South Australia. These hospitals incorporate all tertiary referral services in the state of South Australia. All surgeries were performed by 21 upper gastrointestinal surgeons. We excluded patients under 18 years-of-age, emergency surgeries, cardiomyotomies, and hiatal repairs performed as part of a bariatric operation. This study received ethics approval from the South Adelaide Local Health Network Human Research Ethics committee (HREC 233.20).

**Surgical management**

All patients with a symptomatic hiatus hernia confirmed on preoperative investigations were offered surgical repair. These techniques are described elsewhere.[10] The operative approach (laparoscopic, laparoscopic to open or open), type of hiatal repair (posterior, anterior or both), extent of fundoplication (90, 180, 270 or 360 degrees), use of calibrating bougie, division of short gastric vessels, and excision of sac were at the surgeon's discretion. In 86% of patients, an esophagogram was performed routinely on day one or two post-surgery to detect complications amenable to early reintervention. Patients were typically transitioned from ice chips to a puree diet on the first postoperative day provided there were no radiological or clinical signs of esophageal leak, obstruction or hernia recurrence.

**Postoperative esophagograms**

The aims of postoperative esophagograms were to detect any problems amenable to early laparoscopic or endoscopic reintervention, and to confirm the integrity of the hiatal repair at discharge. During this procedure, either barium, omnipaque or gastrografin contrast medium was administered orally. Real-time images of contrast flow through the esophagus and stomach were acquired using fluoroscopy in the erect frontal, left oblique and prone positions. All images were interpreted by a radiologist examining for evidence of esophageal obstruction (complete contrast hold-up above the gastroesophageal junction), gastroesophageal perforation (contrast extravasation) and hernia recurrence (presence of a gastric bubble, rugal folds or wrap above the diaphragm) (**Figure 1**). Incidental findings such as acute gastric dilatation and abnormal gastric orientation were also reported. If appearances on postoperative esophagograms were unsatisfactory, the operation site was reinspected laparoscopically or endoscopically, and actions taken on the basis of intraoperative findings.

**Data collection and study endpoints**

Data was extracted from a computerized database (FileMaker Pro v12) onto a universal electronic proforma. This included patient demography, medical comorbidities, surgical history, hernia characteristics, esophagogram findings, operative details, and clinical outcomes. All esophagogram findings on record were cross-checked with their original reports and classified by whether they were clinically evident or not. Symptomatic re-herniation was defined by the presence of chest and epigastric pain in association with nausea, retching or vomiting. Esophageal obstruction was defined by inability to swallow and regurgitation of saliva and liquids. Clinical perforation was defined by chest and epigastric pain after drinking. This may be associated with signs of sepsis and peritonism. At one-year post-surgery, all patients were sent a structured questionnaire to assess their symptom outcome. The questionnaire assessed the degree of heartburn, dysphagia to solids and liquids, overall satisfaction and willingness to repeat the same operation. As previously reported,[11] 0-10 analog scores were used to quantify symptom severity (0=no symptoms, 10=severe symptoms) and satisfaction (0=highly dissatisfied, 10=highly satisfied).

**Statistical analysis**

Categorical variables were analyzed using Fisher's exact test. Student's *t*-test or Mann Whitney's *U*-test were used to analyze continuous parametric and non-parametric variables respectively. A two-tailed $p<0.05$ and 95% confidence interval around the odds ratio that did not cross one was considered statistically significant. Statistical analyses were conducted using Prism v8 (GraphPad Software).

**Results**

**Findings from 1571 postoperative esophagograms**

In total, 1829 primary hiatus hernia repairs were performed. Of these, 1571 (85.9%) patients underwent an esophagogram within two days following their repair (**Table 1**). Expected postoperative changes were seen in 96.8% of cases. The most common radiographic abnormality was acute re-herniation (1.5%), followed by gastric dilatation (0.8%), esophageal obstruction (0.6%), and gastroesophageal perforation (0.3%). Importantly, no patient aspirated contrast medium in this study. The incidence of radiographic abnormality increased with hernia size (Intra-thoracic stomach: 5.3%, >5cm hernia: 2.7%, <5cm hernia: 1.4%, p=0.001), as did the rate of re-herniation (Intra-thoracic stomach: 4.1%, >5cm hernia: 1.0%, <5cm hernia: 0.9%, p=0.002). At the time of esophagogram, 3 of 4 (75.0%) perforations and 8 of 9 (88.9%) obstructions were symptomatic. In comparison, 22 of 24 (91.2%) hernia recurrences and 11 of 13 (84.6%) gastric dilatations were clinically silent.

The 14-day (early) reoperation rate was 2.4% (44/1829 cases). Surgical revision was carried out for all patients with a clinically obstructed esophagus. Interestingly, of the 7 perforations, only 4 were detected on esophagogram. One of these was asymptomatic at the time. In the remaining 3 cases, contrast extravasation was not seen, and these patients represented back to hospital four, seven, and nine days post-discharge with sepsis. All patients with a perforation underwent operative reintervention. Despite only 2 symptomatic hernia recurrences, 21 of 24 (87.5%) patients with re-herniation received surgical correction within three days of their primary hiatus hernia repair. No patient with acute gastric dilatation required reoperation. However, this diagnosis altered ward-based management including insertion of nasogastric tubes, dietary modifications, use of prokinetic agents, rationalization of existing medications, and delayed discharge.

In this study, the negative predictive value of a routine postoperative esophagogram for early reoperation was 99.7%. Conversely, the positive predictive values for an early reoperation to treat hernia recurrence, gastroesophageal perforation and esophageal obstruction are 87.5%, 100.0% and 88.9% respectively. Overall, 1 in 31 esophagograms altered clinical management, and 1 in 48 esophagograms resulted in an early reoperation. This threshold decreased with increasing hernia size (Intra-thoracic stomach: 1 in 29, >5cm hernia: 1 in 44, <5cm hernia: 1 in 87).

**The impact of routine esophagograms on the outcomes of early reoperations following hiatus hernia repair**

Patients who did or did not undergo a routine postoperative esophagogram were compared (**Table 2**). Besides higher rates of cardiorespiratory diseases amongst those who received routine esophagograms, the two groups were similar with respect to their baseline characteristics.

In the 44 patients who required an early reoperation, 37 received an esophagogram while 7 did not. Despite comparable indications for reintervention between these two groups (**Table 3**), all patients who did not undergo a prior esophagogram were symptomatic of their complications at the time of surgery. This is compared to only 45.9% of those whose complications were detected on routine esophagograms. Overall, this test resulted in early diagnosis and treatment of esophageal obstruction, perforation and re-herniation following hiatus hernia repair.

Furthermore, the use of esophagograms routinely was associated with a significantly higher rate of completing the reoperation laparoscopically, lower rates of mediastinitis and peritonitis, no gastric resections, shorter reoperative time, and decreased unplanned intensive care admissions (**Table 3**). Routine use of esophagograms also led to reduced rates of pulmonary complications, delirium, mediastinal and intra-abdominal abscesses, which together decreased length-of-stay after reoperation. These findings demonstrate that routine esophagograms can minimize the morbidity associated with early reoperations following hiatus hernia repair.

**The impact of routine esophagograms on the outcomes of reoperations for hernia recurrences**

We hypothesized that a key benefit of routine postoperative esophagograms is the detection of asymptomatic hernia recurrences. This enables early correction within 3-4 days of the original operation, at a time when adhesions and fibrosis have not formed, delivering corrective surgery with minimal morbidity. Conversely, we contend that without routine esophagograms, these occult re-herniations will pass undetected, and then might present as later symptomatic recurrences, when adhesions and peri-hiatal fibrosis may render revisional surgery much more difficult.

To test these hypotheses, we compared the 19 patients who underwent an early reoperation for an esophagogram-detected asymptomatic re-herniation with those 80 patients who had undergone a late reoperation for symptomatic recurrence (**Table 4**). In the latter group, their median (range) time from index hernia repair to reoperation was 32.5 (2.8-193.9) months. Despite similar demographics, body mass index, and comorbidities between the two groups, an early reoperation was completed in a significantly shorter period of time. This was associated with no open surgery, no intraoperative or postoperative complications, and a shorter length-of-stay post reoperation. In contrast, late reoperations had more intraoperative and postoperative complications owing to adhesions that obscured view, which resulted in injuries to nearby structures and more open surgeries. Importantly, at one-year follow-up, patients who had an early reoperation reported less dysphagia to solids and a greater satisfaction with their hernia repair than the late reoperative group. Furthermore, no patients in the early reoperative group, compared with 25.5% of patients in the late reoperative group, regretted their initial decision to undergo surgery.

We next compared those who underwent an early reoperation for asymptomatic re-herniation with the 1786 patients who did not receive any reinterventions (**Table 5**). Although reoperation extended the length-of-stay by 2 extra days, we found no differences in symptomatology and satisfaction outcomes between these two groups at one-year follow-up. Additionally, no patients in the early reoperative group required further surgery for hernia recurrences at one year. Conversely, we identified 3 patients with an esophagogram-detected asymptomatic re-herniation that did not undergo early reoperation. One of these patients received surgery for a symptomatic hiatus hernia within one year.

Collectively, these results suggest that routine esophagograms reduce the need and potential morbidity of late revisional surgery by detecting asymptomatic re-herniations early, to enable prompt correction. This practice achieves satisfactory functional outcomes.

**Discussion**

This is the first study to quantify the clinical utility of routine esophagograms following hiatus hernia repair. We have shown that this test, applied routinely, leads to early diagnosis and timely management of gastroesophageal leaks, esophageal obstructions and hernia recurrences regardless of whether patients are symptomatic or not. In doing so, this minimizes patient morbidity. We also demonstrated that early surgical correction of an esophagogram-detected asymptomatic hernia recurrence not only prevents progression to gastric strangulation, which incurs significant morbidity, but avoids more challenging revisional surgeries later on. Symptomatically, this approach achieves better outcomes than late revisional surgery, whilst remaining comparable to those without an early reoperation. Moreover, we found that routine esophagograms carry minimal risk, with no aspiration events in 1571 cases.

There is considerable debate in the literature between routine versus selective use of esophagograms following anti-reflux and hiatus hernia surgeries.[3, 5-8, 12] Proponents of the latter argue that its routine use unnecessarily extends hospital stay, minimally affects patient management, unreliably detects postoperative complications, and poorly predicts the need for reoperations.[5-8] These conclusions however, are drawn from retrospective single institution studies that are limited in power (N=92-391) or non-comparative in design. Furthermore, only one report has focused specifically on hiatus hernia surgery.[8] Contrary to these findings, our study, based on the outcomes of 1829 hiatus hernia repairs, has shown that esophagograms can be integrated into routine care without increasing hospital stay. Additionally, we found that this test informs decision-making and the need for early reintervention. Analogous to intraoperative cholangiograms performed during cholecystectomies, its clinical utility (1 in 20-63 tests) is similar to that of postoperative esophagograms (1 in 31 tests) defined in this study.[13, 14] We note that intraoperative cholangiography is now adopted routinely by many surgeons for cholecystectomies.[15] We advocate that postoperative esophagograms share the same status for hiatus hernia repairs.

Consistent with other reports,[8] we found that the sensitivity of an esophagogram to detect a gastroesophageal leak is low (57.1%) despite its high specificity (100.0%). The sensitivity of this test may be influenced by the location and size of the leak, thus highlighting the need to capture multiple views with the patient placed in different positions during the test. Our findings suggest that whilst a routine esophagogram may diagnose a leak before it becomes clinically apparent, the

lack of contrast extravasation does not exclude this differential should the patient present symptomatically in the near future. In this scenario, cross-sectional imaging with oral contrast or repeating the esophagogram should be promptly undertaken to diagnose or exclude an underlying gastroesophageal perforation.

We recognize that the risk of early reoperation following anti-reflux and hiatus hernia surgery is low, a point that is often used to argue against performing routine esophagograms.[5, 7, 8] However, despite its low incidence, we show that delayed diagnosis of acute re-herniations, esophageal obstructions or leaks incur significant morbidity and mortality. Indeed, the morbidity rate for patients who underwent an early reoperation without a prior esophagogram was 85.7%. Their 30-day mortality rate was 14.3%. This is compared to 13.5% and 0.0% respectively in those whose complications were diagnosed on an esophagogram before reoperation. Until now, this aspect has been under-appreciated by the literature. Our findings suggest that performing esophagograms routinely post hiatus hernia repair is a simple strategy to rescue patients from major morbidity and mortality.

Allowing for the possibility that early and late re-herniations may have different etiologies which may affect their ultimate outcomes, we recognize that routine postoperative esophagograms may not capture all potential late re-herniations, or change their natural history. Despite this our findings support early surgical correction of asymptomatic re-herniations detected on esophagograms. This is based on three reasons. First, these hernias may become symptomatic in the future if left alone. Surgery in these instances may be complicated by dense adhesions, resulting in higher rates of intraoperative and postoperative complications. This may predispose to poorer functional outcomes and patient dissatisfaction. Second, our calculations suggest that 2 of 3 (% symptomatic recurrence without esophagogram/% asymptomatic recurrence with esophagogram: 0.8%/1.2%) asymptomatic recurrences are at risk of strangulation which carries significant morbidity. Third, correcting re-herniations early achieves equivalent functional outcomes as those who did not undergo a reoperation, with minimal extra morbidity in most cases.

We acknowledge the lack of formal quality-of-life assessment, cost analysis, and longer-term follow-up of patients in this study. The choice to perform postoperative esophagograms was at the treating surgeon's discretion. This may confound the results of this study as surgeons who routinely order postoperative esophagograms may be more risk-averse. Additionally, the value of postoperative esophagograms to self-auditing, quality control, education and training was not evaluated.

Overall, in this large multicenter cohort study, we have shown that postoperative esophagograms can minimize the morbidity associated with early and late reoperations. Therefore, its use routinely following hiatus hernia repair should be encouraged

**References**


1. Schlottmann F, Strassle PD, Farrell TM, et al. Minimally Invasive Surgery Should Be the Standard of Care for Paraesophageal Hernia Repair. *J Gastrointest Surg* 2017; 21(5):778-784.

2. Andujar JJ, Papasavas PK, Birdas T, et al. Laparoscopic repair of large paraesophageal hernia is associated with a low incidence of recurrence and reoperation. *Surg Endosc* 2004; 18(3):444-7.

3. Tsunoda S, Jamieson GG, Devitt PG, et al. Early reoperation after laparoscopic fundoplication: the importance of routine postoperative contrast studies. *World J Surg* 2010; 34(1):79-84.

4. Tog C, Liu DS, Lim HK, et al. Risk factors for delayed gastric emptying following laparoscopic repair of very large hiatus hernias. *BJS Open* 2017; 1(3):75-83.

5. Contini S, Scarpignato C. Early esophageal transit study after laparoscopic fundoplication: how useful is it? *Am J Surg* 2002; 183(3):226-31.

6. Szwerc MF, Gagne DJ, Wiechmann RJ, et al. Immediate radiographic assessment following laparoscopic antireflux operations is unnecessary. *Surg Endosc* 2002; 16(1):64-6.

7. Shahzad K, Menon A, Turner P, et al. Routine versus selective contrast imaging to identify the need for early re-intervention following laparoscopic fundoplication: A retrospective cohort study. *Int J Surg* 2015; 20:123-7.

8. Robertson-More C, Prasad S, Gill R, et al. Early Routine Use of Upper GI Contrast Series Post Paraesophageal Hernia Repair: A Single Institution Consecutive Case Series. *Surg Laparosc Endosc Percutan Tech* 2019; 29(3):203-206.

9. Yau P, Watson DI, Devitt PG, et al. Laparoscopic antireflux surgery in the treatment of gastroesophageal reflux in patients with Barrett esophagus. *Arch Surg* 2000; 135(7):801-5.

10. Watson DI, Thompson SK, Devitt PG, et al. Laparoscopic repair of very large hiatus hernia with sutures versus absorbable mesh versus nonabsorbable mesh: a randomized controlled trial. *Ann Surg* 2015; 261(2):282-9.

11. Liu DS, Tog C, Lim HK, et al. Delayed Gastric Emptying Following Laparoscopic Repair of Very Large Hiatus Hernias Impairs Quality of Life. *World J Surg* 2018; 42(6):1833-1840.

12. Yau P, Watson DI, Devitt PG, et al. Early reoperation following laparoscopic antireflux surgery. *Am J Surg* 2000; 179(3):172-6.

13. Low SC, Ng FC, Yap YL, et al. Operative cholangiography. *Singapore Med J* 1992; 33(3):252-4.

14. Corbitt JD, Jr., Leonetti LA. One thousand and six consecutive laparoscopic intraoperative cholangiograms. *JSLS* 1997; 1(1):13-6.

15. Hope WW, Fanelli R, Walsh DS, et al. SAGES clinical spotlight review: intraoperative cholangiography. *Surg Endosc* 2017; 31(5):2007-2016.

**Figure legends**

**Figure 1.** Esophagogram demonstrating evidence of obstruction (A), leak (B), and re-herniation (C) following hiatus hernia repair. White arrow indicates level of complication.

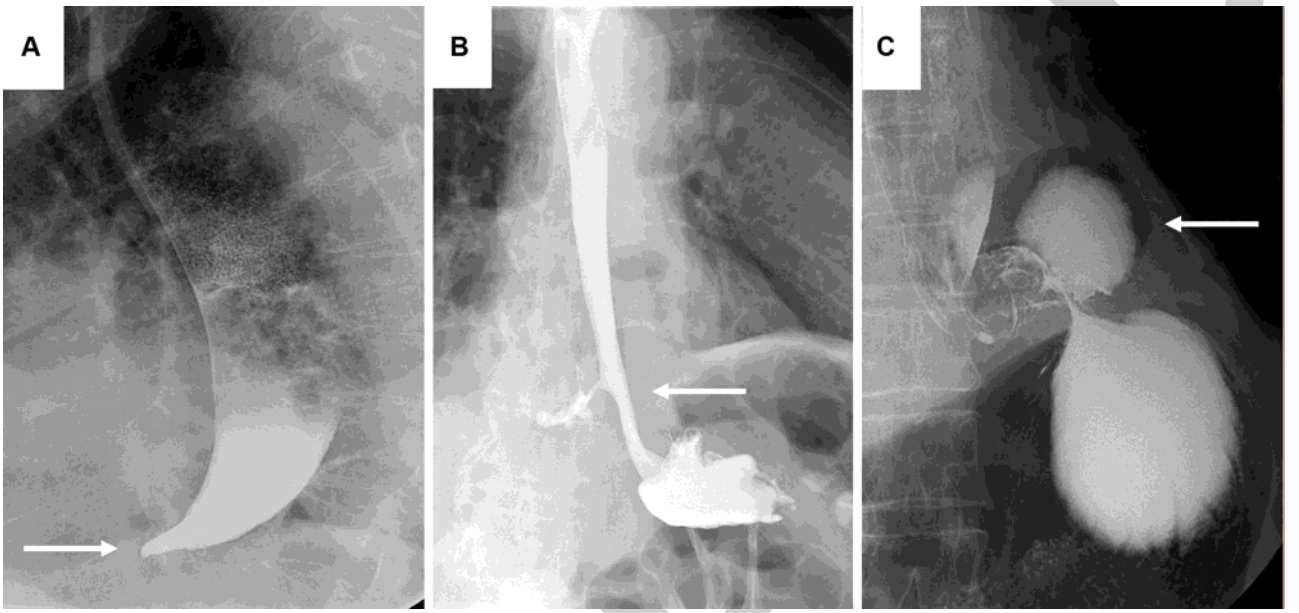


*Table 1. Correlation of esophagogram findings with symptomatology and early reoperation*

| | **X-ray outcome** | **Symptomatic #** | **Reoperation** |
|---|---|---|---|
| **Esophagogram outcomes** | **N=1571** | | **<14 days** |
| Expected postoperative changes, n (%) | 1519 (96.8) | - | 4 (0.3) * |
| Re-herniation, n (%) | 24 (1.5) | 2 (8.3) | 21 (87.5) |
| Complete esophageal obstruction, n (%) | 9 (0.6) | 8 (88.9) | 8 (88.9) |
| Gastroesophageal perforation, n (%) | 4 (0.3) | 3 (75.0) | 4 (100.0) |
| Acute gastric dilatation, n (%) | 13 (0.8) | 2 (15.4) | 0 (0.0) |
| Volvulus orientation, n (%) | 1 (0.1) | 0 (0.0) | 0 (0.0) |
| Contrast aspiration, n (%) | 0 (0.0) | - | - |

* Reoperation for 3 esophageal leaks not seen on esophagogram and 1 postoperative bleeding, # Symptomatic at time of esophagogram

*Table 2. Demographic and procedure-related information*

| **Characteristics** | **Routine esophagograms N=1571** | **No esophagograms N=258** | **P valve** |
|---|---|---|---|
| Age, median (IQR) | 63 (54-72) | 62 (50-74) | 0.38 |
| Gender, male, n (%) | 600 (38.2) | 97 (37.6) | 0.89 |
| Body mass index, kg/m$^2$, mean (SD) | 29.7 (4.4) | 29.7 (4.1) | 0.78 |
| Co-morbidities, n (%) | | | |
| Chronic kidney injury | 43 (2.7) | 3 (1.2) | 0.19 |
| Diabetes | 81 (5.2) | 14 (5.4) | 0.88 |
| Chronic airway disease | 340 (21.6) | 35 (13.6) | **0.003** |
| Cardiovascular disease | 429 (27.3) | 40 (15.5) | **<0.001** |
| Previous upper abdominal surgery | 874 (55.6) | 130 (50.4) | 0.12 |
| Hernia type, n (%) | | | 0.84 |
| Type 1 (Sliding) | 780 (49.6) | 130 (50.4) | |
| Type 2 (Rolling) | 309 (19.7) | 67 (26.0) | |
| Type 3/4 (Mixed) | 482 (30.7) | 61 (23.6) | |
| Hernia size, n (%) | | | 0.10 |
| <5 cm (small/medium) | 663 (42.2) | 123 (47.7) | |
| >5 cm (large) | 767 (48.8) | 105 (40.7) | |
| Intra-thoracic stomach | 141 (9.0) | 30 (11.6) | |
| Operative approach, n (%) | | | 0.32 |
| Laparoscopic | 1552 (98.8) | 252 (97.7) | |
| Laparoscopic to open conversion | 17 (1.1) | 5 (1.9) | |
| Open | 2 (0.1) | 1 (0.4) | |
| Hiatal repair, n (%) | | | 0.21 |
| Posterior | 1242 (79.1) | 213 (82.6) | |
| Anterior | 21 (1.3) | 9 (3.5) | |
| Anterior and posterior | 308 (19.6) | 36 (14.0) | |
| Fundoplication, n (%) | | | 0.13 |
| Total | 328 (20.9) | 43 (16.7) | |

| | | | | |
|---|---|---|---|---|
| | Partial | 1243 (79.1) | 215 (83.3) | |
| Operation time, min, mean (SD) | | 89.9 (41.4) | 93.0 (41.1) | 0.27 |
| Time to esophagogram, days, median (IQR) | | 1 (1-1) | - | - |
| Length of stay, days, median (IQR) | | 2 (2-3) | 2 (2-2) | 0.66 |
| Reoperation <14 days, n (%) | | 37 (2.4) | 7 (2.7) | 0.66 |

IQR: interquartile range, SD: standard deviation

*Table 3. Outcomes of early reoperations in patients with or without routine esophagograms*

| Outcomes | Routine esophagograms N=37 | No esophagograms N=7 | P value |
|---|---|---|---|
| Indications for early reoperations, n (%) | | | 0.09 |
| Re-herniation | 21 (56.8) | 2 (28.6) | |
| Gastro-esophageal perforation | 7 (18.9) | 3 (42.9) | |
| Esophageal obstruction | 8 (21.6) | 1 (14.3) | |
| Mediastinal collection | 0 (0.0) | 1 (14.3) | |
| Intra-abdominal bleeding | 1 (2.7) | 0 (0.0) | |
| Clinically symptomatic at diagnosis, n (%) | 17 (45.9) | 7 (100.0) | **0.011** |
| Time from index surgery to diagnosis | | | **0.041** |
| Days, median (IQR) | 2 (1-3) | 3 (2-7) | |
| Days, mean (SD) | 2.4 (2.2) | 3.9 (2.6) | |
| Time from index surgery to reoperation | | | **0.037** |
| Days, median (IQR) | 2 (1-3) | 3 (2-8) | |
| Days, mean (SD) | 2.4 (2.2) | 4.3 (3.1) | |
| Reoperative approach, n (%) | | | **0.034** |
| Laparoscopic +/- endoscopic | 33 (89.2) | 4 (57.1) | |
| Laparoscopic to open conversion | 3 (8.1) | 1 (14.3) | |
| Open | 1 (2.7) | 2 (28.6) | |
| Mediastinitis/Peritonitis, n (%) | 4 (10.8) | 3 (42.9) | **0.034** |
| Gastric resection for necrosis, n (%) | 0 (0.0) | 2 (28.6) | **0.022** |
| Procedural time, min, mean (SD) | 52.2 (38.6) | 158.3 (105.4) | **0.006** |
| Intraoperative bleeding, n (%) | 1 (2.7) | 0 (0.0) | 1.00 |
| Postoperative complications, n (%) | | | |
| Overall | 5 (13.5) | 6 (85.7) | **<0.001** |
| Bleeding | 1 (2.7) | 0 (0.0) | 1.00 |
| Intra-abdominal abscess | 0 (0.0) | 3 (42.9) | **0.003** |
| Mediastinal abscess | 0 (0.0) | 2 (28.6) | **0.022** |
| Respiratory | 4 (10.8) | 6 (85.7) | **0.002** |

| | | | |
|---|---|---|---|
| Cardiac | 1 (2.7) | 2 (28.6) | 0.06 |
| Delirium | 1 (2.7) | 3 (42.9) | **0.010** |
| Urological | 1 (2.7) | 2 (28.6) | 0.06 |
| Wound breakdown | 1 (2.7) | 0 (0.0) | 1.00 |
| Unplanned ICU admission, n (%) | 6 (16.2) | 6 (85.7) | **<0.001** |
| Unplanned return to theatre, n (%) | 3 (8.1) | 0 (0.0) | 1.00 |
| 30-day mortality, n (%) | 0 (0.0) | 1 (14.3) | 0.16 |
| Length of stay post reoperation | | | **0.009** |
| Days, median (IQR) | 3 (2-6) | 16 (7-32) | |
| Days, mean (SD) | 7.3 (18.2) | 18.3 (13.6) | |

ICU: intensive care unit, IQR: interquartile range, SD: standard deviation

*Table 4. Outcomes of early versus late reoperations for hernia recurrence*

| Outcomes | Early reoperation for asymptomatic recurrence N=19 | Late reoperation for symptomatic recurrence N=80 | P value |
|---|---|---|---|
| Time from index surgery, days, median (IQR) | 1 (1-2) | 975 (548-1797) | **<0.001** |
| Age, years, median (IQR) | 65 (60-76) | 64 (55-71) | 0.56 |
| Gender, male, n (%) | 5 (26.3) | 22 (27.5) | 1.00 |
| Body mass index, kg/m$^2$, mean (SD) | 28.5 (2.3) | 29.4 (3.4) | 0.32 |
| Co-morbidities, n (%) | | | |
| Any | 14 (73.7) | 53 (66.3) | 0.60 |
| Chronic kidney injury | 1 (5.3) | 1 (1.3) | 0.35 |
| Diabetes | 0 (0.0) | 4 (5.0) | 1.00 |
| Chronic airway disease | 6 (31.6) | 15 (18.8) | 0.23 |
| Cardiovascular disease | 7 (36.8) | 26 (32.5) | 0.79 |
| Others | 8 (42.1) | 33 (41.3) | 1.00 |
| Operative approach, n (%) | | | **0.041** |
| Laparoscopic | 19 (100.0) | 65 (81.3) | |
| Laparoscopic to open conversion | 0 (0.0) | 10 (12.5) | |
| Open | 0 (0.0) | 5 (6.3) | |
| Operation time, min, mean (SD) | 39.0 (23.1) | 136.5 (40.2) | **<0.001** |
| Intraoperative complications, n (%) | | | |
| Overall | 0 (0.0) | 15 (18.8) | **0.041** |
| Adhesions requiring open conversion | 0 (0.0) | 7 (8.8) | 0.34 |
| Lung laceration | 0 (0.0) | 1 (1.3) | 1.00 |
| Splenic laceration | 0 (0.0) | 2 (2.5) | 1.00 |
| Liver laceration | 0 (0.0) | 3 (3.8) | 1.00 |
| Gastric perforation | 0 (0.0) | 2 (2.5) | 1.00 |
| Postoperative complications, n (%) | | | |
| Overall | 0 (0.0) | 11 (13.8) | **0.043** |
| Bleeding | 0 (0.0) | 1 (1.3) | 1.00 |

| | | | |
|---|---|---|---|
| Respiratory | 0 (0.0) | 8 (10.0) | 0.35 |
| Cardiac arrhythmias | 0 (0.0) | 1 (1.3) | 1.00 |
| Ileus | 0 (0.0) | 4 (5.0) | 1.00 |
| Venous thromboembolism | 0 (0.0) | 1 (1.3) | 1.00 |
| Acute kidney injury | 0 (0.0) | 1 (1.3) | 1.00 |
| Unplanned ICU admission, n (%) | 0 (0.0) | 1 (1.3) | 1.00 |
| Unplanned return to theatre, n (%) | 0 (0.0) | 3 (3.8) | 1.00 |
| Length of stay post reoperation | | | **0.023** |
| Days, median (IQR) | 2 (2-4) | 3 (2-5) | |
| Days, mean (SD) | 2.7 (1.5) | 4.1 (3.4) | |
| Outcomes at 1-year post surgery | | | |
| Surgery for hernia recurrence, n (%) | 0 (0.0) | 2 (2.5) | 1.00 |
| Heartburn score, median (IQR) * | 1 (0-4) | 2 (0-5) | 0.39 |
| Dysphagia to liquid score, median (IQR) * | 0 (0-0) | 0 (0-2) | 0.30 |
| Dysphagia to solids score, median (IQR) * | 0 (0-2) | 1 (0-5) | **0.045** |
| Satisfaction score, median (IQR) * | 10 (9-10) | 8 (4-10) | **0.012** |
| Would repeat surgery, n (%) * | 13 (100.0) | 41 (74.5) | **0.041** |

ICU: intensive care unit, IQR: interquartile range, SD: standard deviation, * data available for 13 (early) and 55 (late) patients

*Table 5. Outcomes of early versus no reoperations*

| Outcomes | Early reoperation for asymptomatic recurrence N=19 | No Early reoperation N=1785 | P value |
|---|---|---|---|
| Total length of stay, days, mean (SD) | 4 (3-5) | 2 (2-3) | **0.002** |
| Outcomes at 1-year post surgery | | | |
| Surgery for hernia recurrence, n (%) | 0 (0.0) | 7 (0.4) | 1.00 |
| Heartburn score, median (IQR) * | 1 (0-4) | 0 (0-2) | 0.31 |
| Dysphagia to liquid score, median (IQR) * | 0 (0-0) | 0 (0-1) | 0.55 |
| Dysphagia to solids score, median (IQR) * | 0 (0-2) | 0 (0-3) | 0.23 |
| Satisfaction score, median (IQR) * | 10 (9-10) | 10 (8-10) | 0.43 |
| Would repeat surgery, n (%) * | 13 (100.0) | 1085 (92.2) | 0.62 |

IQR: interquartile range, SD: standard deviation, * data available for 13 (early) and 1177 (No) patients