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Gastric tube necrosis following minimally invasive oesophagectomy is a learning curve issue

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ABSTRACT

INTRODUCTION Gastric tube necrosis following oesophagectomy is thought to have an increased association with a minimally invasive technique. Some suggest gastric ischaemic preconditioning may reduce ischaemic complications. We discuss our series of 155 consecutive minimally invasive oesophagectomies (MIOs), including a number of cases of gastric tube ischaemia, of which 4 (2.6%) developed conduit necrosis.

METHODS Data were collected prospectively of MIOs carried out by a single surgeon between 2005 and 2011. Cases of gastric tube necrosis were identified.

RESULTS Overall, 155 patients were identified. The inpatient mortality rate was 2.6%. Gastric tube necrosis occurred in four patients (2.6%). An ultrasonic dissector injury to the gastroepiploic arcade had occurred in two cases. In another case, the gastric tube was strangulated in the hiatus. In the remaining case, no clear mechanical cause was identified. All 4 cases occurred within the first 73 cases. The gastric tube necrosis rate of the first 50 cases versus cases 51–155 was 4% and 2% respectively (p=0.5948). The anastomotic leak rate in these two cohorts was 18% and 7% respectively (p=0.0457). There was a significant reduction in overall gastric tube complications from 22% to 10% following the learning curve of the initial 50 cases (p=0.0447).

CONCLUSIONS In our series, gastric tube necrosis appears to be a learning curve issue. Prophylactic measures such as ischaemic preconditioning become less relevant as the operating surgeon's experience increases. Instead, meticulous attention to preserving the gastroepiploic arcade, avoidance of tension in the tube and careful positioning of the gastric conduit through an adequately sized hiatus are key factors.

KEYWORDS

Minimally invasive – Oesophagectomy – Ischaemia – Necrosis

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Minimally invasive oesophagectomies (MIOs) have become increasingly popular, with 659 being carried out in England and Wales between 2007 and 2009, accounting for 30% of all oesophagectomies performed during this period.[1] The transition from an open procedure to an MIO has raised some concerns. In cancer patients, the initial concerns about lymph gland dissection and oncological parity with open surgery have been shown to be largely misplaced.[2] Another concern is the perceived increased incidence of gastric conduit ischaemia, necrosis and anastomotic leakage, which may result in increased morbidity and mortality (Fig 1).[1]

The published rates of early gastric tube ischaemic complications after MIO vary from 3.3% to 10.5%.[1,3–5] This is in contrast to open oesophagectomies where the reported rates are 0.5–7.4%.[1,6] The consensus group for the Association of Upper Gastrointestinal Surgeons (AUGIS) stated that the learning curve for a surgeon developing his or her MIO technique is substantial, and thought to be between 20 and 50 cases.[7] We have previously shown a learning curve in relation to the lymph gland yield when introducing MIO for cancer.[6] We therefore hypothesised that the increased incidence of gastric tube ischaemic complications associated with MIO is also a learning curve issue.

The aims of this study were to identify all those patients who developed gastric tube necrosis and/or leakage in our large series of MIOs, and to discuss the presentation, aetiology, management and outcome for each of these cases. The literature regarding gastric tube necrosis is reviewed and discussed alongside our own findings to determine a strategy to avoid these complications.

Methods

The case notes of all consecutive cases of MIO carried out in our unit between 2005 and 2011 were reviewed. Patient data were identified prospectively and collated on an Access® database (Microsoft, Redmond WA, US). Inclusion criteria were all patients who had an oesophagogastrectomy with

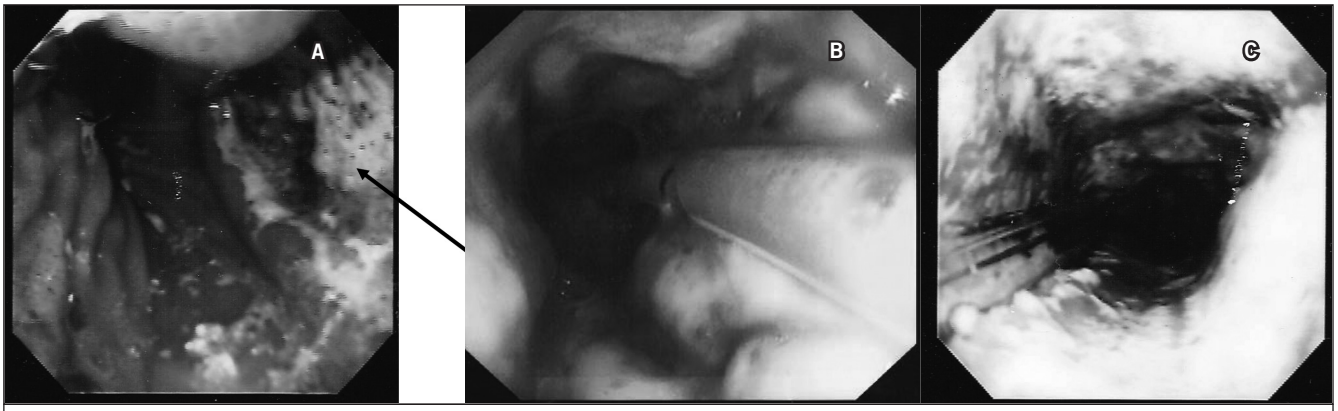


Figure 1 Gastroscopic images with varying degrees of ischaemia of the tip of the gastric tube: a wedge shaped segment of complete necrosis around the proximal staple line of the gastric tube (arrow) (A), circumferential partial ischaemia of the proximal gastric tube with islands of necrosis surrounded by viable mucosa (B) and circumferential complete necrosis of the proximal gastric tube (C)

a fully laparoscopic abdominal phase and either video assisted thoracoscopic surgery (VATS) or a mini-thoracotomy. Patients whose laparoscopy was converted to a laparotomy were included.

Details collected included patient demographics, preoperative chemoradiotherapy details, intraoperative details, postoperative complications and final histology. To assess for a learning curve effect on gastric tube complications, we arbitrarily compared the outcome of the first 50 cases with the subsequent 105.

Operative technique

All operations were carried out by or under the close supervision of a single consultant surgeon who had personal experience of over 100 open oesophagectomies as well as extensive experience in advanced laparoscopic surgery. Patients were intubated using a double lumen endotracheal tube. All patients received a thoracic epidural prior to commencement of surgery. The patient was positioned in a Lloyd-Davies position with the operating surgeon standing between the patient's legs. Usually, five ports were introduced. An ultrasonic dissector was used to mobilise the stomach along the greater curve while taking care to preserve the gastroepiploic arcade. All patients underwent pyloroplasty. Lymph node harvesting was performed through the use of the Harmonic® scalpel (Ethicon Endo-Surgery, Cincinnati, OH, US). Ligaclips were used to secure the left gastric artery.

Dissection into the chest was carried out for at least 10cm in order to facilitate the thoracic phase of the operation, according to the principles of total adventitial resection of the cardia (TARC), as described previously.[8] If the hiatal orifice after TARC was deemed too wide, the anterior tendinous part of the hiatus was repaired with size 0 Ethibond® sutures (Ethicon, Somerville, NJ, US). Overtightening of the hiatus is avoided by 'sizing' the orifice with laparoscopic forceps.

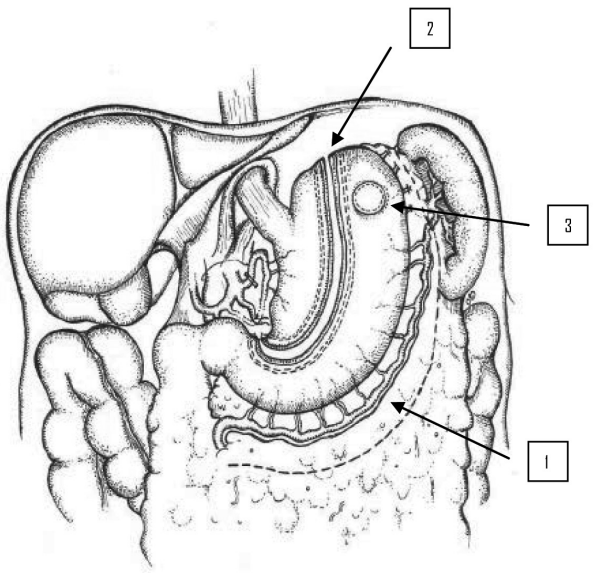
For oncological reasons, the lesser curve of the stomach and lymph nodes were removed by creating a greater curve tube. The gastric tube was constructed intracorporeally starting from below the incisura approximately 5cm proximal to the pylorus through the use of an Echelon™ 60mm Endopath® (Ethicon Endo-Surgery) stapling gun. The width of the gastric tube was approximately 5cm. The tube was not fully divided at the fundus to enable later pull-up into the thorax. Left and right transhiatal chest drains were introduced under direct vision through the abdominal port sites.[9]

For the thoracic phase, the patient was in the left lateral position for a posterolateral thoracotomy incision. In the case of the VATS procedures, two or three 12mm thoracoscopic ports were inserted, allowing the thoracotomy incision length to be reduced to 10–15cm with sparing of the latissimus dorsi and serratus anterior muscles. The azygos vein was divided before harvesting of the paraoesophageal and subcarinal nodes. The oesophagus was divided in the upper mediastinum and the intrathoracic end-to-side oesophagogastric anastomosis to the anterior wall of the gastric tube (Fig 2) was fashioned either through hand sewing or the use of a 25mm CEEA™ gun (Covidien, Dublin, Ireland).[10] A triple lumen nasojejunal tube (Freka®; Fresenius Kabi, Bad Homburg, Germany) was placed under flexible gastroscopic vision to allow gastric decompression and jejunal feeding in the immediate postoperative phase.

Perioperative care

The general pre and postoperative care was instigated through the use of patient management protocols. Postoperatively, all patients were nursed in an overnight intensive recovery unit and extubated when physiologically stable. A systolic blood pressure of around 120mmHg was maintained through the combination of crystalloid infusions and low dose noradrenaline infusion. Blood transfusion was considered in all patients with a postoperative haemoglobin level of <8g/dl.

On the first postoperative day, patients were transferred to the surgical high dependency unit or a normal surgical ward depending on their clinical and physiological param-



1. Leave 5–10cm width of omentum around stomach
2. Start cut at incisura on antrum
3. Make anastomosis not at the tip but rather slightly lower at the level of the upper pole of the spleen close to the short gastric vessels

Figure 2 Illustration showing formation of the gastric tube

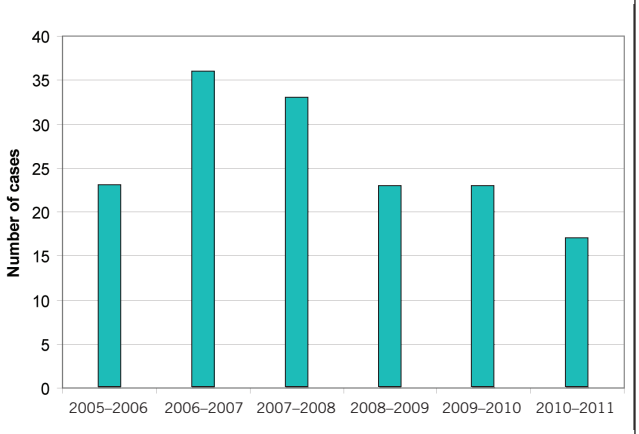


Figure 3 Number of oesophagectomies carried out per year

Table 1 Patient characteristics and pathology

Median age (range)	63 (41–82)
<55 years	31 (20%)
<45 years	7 (5%)
Male-to-female ratio	2.88
ASA grade:	
1	5
2	95
3	34
Not recorded	21
Histopathology:	
Adenocarcinoma	112 (72%)
Squamous cell carcinoma	23
Adenosquamous carcinoma	4
Leiomyoma	3
Gastrointestinal stromal tumour	1
High grade dysplasia	1
Other	1
Not recorded	10
Neoadjuvant chemotherapy	112 (72%)
Unknown	10 (6%)
Median length of tumour (range)	4.4cm (1–15cm)
pTNM classification:	
T0 (complete response)	8
T1	21
T2	44
T3	63
T4	3
Benign	6
Data incomplete	10

ASA = American Society of Anesthesiologists

eters. Patients were allowed sips of water and then built up oral fluids slowly over the first week. Soft food was commenced after a week and the nasojejunal tube removed. For the first 50 cases, routine water soluble contrast swallows were performed on the fifth postoperative day to examine for anastomotic leaks but this practice was thereafter abandoned in favour of selective investigation. Close observation was performed to monitor for early signs of a leak (eg persistent tachycardia, pyrexia, pleural effusion or laboratory indicators of sepsis). These patients underwent contrast computed tomography or a water soluble swallow, followed by gastroscopic assessment under sedation to assess for gastric tube ischaemia and/or a demonstrable anastomotic leak. On discharge, patients were followed up closely at regular intervals.

Results

A total of 158 records were obtained over a 6-year period from May 2005 to April 2011. Two cases were excluded as these were extended total gastrectomies. A further case was excluded as it began as an open procedure. There were therefore 155 cases of laparoscopically assisted Ivor–Lewis oesophagectomies (Fig 3). Of these, 149 operations were carried out as treatment for a primary oesophageal malignancy, the others for resection of benign disease.

Of the 155 patients, 115 were male (Table 1). The median patient age at the time of surgery was 63 years. The mean operating time per case was 280 minutes and the median inpatient stay was 14 days (Table 2).

All 155 cases had a full laparoscopy with no planned laparotomy incision. Two cases were converted to an open procedure, both due to significant intraoperative bleed-

Table 2 Perioperative outcome

Operating time	
Mean (SD)	280 mins (49 mins)
Median (range)	270 mins (181–480 mins)
Blood transfusions	
Patients transfused in first 72 hours	35 (23%)
Patients transfused beyond 72 hours	24 (16%)
Patients not transfused	110 (71%)
Mean units transfused per patient (range)	1.59 (0–24)
Postoperative controlled ventilation	
Mean (SD)	11.6 hrs (21.6 hrs)
Median (range)	11 hrs (2–240 hrs)
Overnight intensive recovery	
Mean (SD)	27.3 hrs (15.9 hrs)
Median (range)	22 hrs (5–94 hrs)
Step-down facility from overnight intensive recovery	19 (12%)
Ward High dependency unit	90 (58%)
Intensive care unit	22 (14%)
Unknown	25 (16%)
Mean primary stay in critical care	
Mean (SD)	8.9 days (15.4 days)
Median (range)	4 days (1–90 days)
Patients readmitted to critical care	14 (9%)
Total length of hospital stay	
Median (range)	14 days (6–210 days)

SD = standard deviation

Table 3 Postoperative complications

Major complications (*n*=59)		**Minor complications** (*n*=100)	
Haemorrhage	5	Wound infection	7
Gastric tube necrosis	4	Atrial fibrillation	13
Septicaemia	3	Unary tract infection	1
Clinical anastomotic leak	8	Jejunostomy site problems	3
Myocardial infarction	2	Gastric tube ischaemia	1
Delayed gastric emptying	1	Radiological anastomotic leak	8
Chyle leak	5	Stricture	2
Pneumonia	27	Pneumothorax	7
Respiratory failure	4	Pleural effusion	33
		Pulmonary oedema	3
		Other	22

Table 4 Patients requiring reoperation

Complication requiring reoperation	**Number of patients**
Gastric tube necrosis	4
Hiatus hernia with intrathoracic bowel	1
Haemorrhage	2
Anastomotic leak	3
Chyle leak	1

ing. In terms of the thoracic component, 128 cases were performed through VATS whereas 10 had a standard thoracotomy incision. In 17 cases, the thoracic approach was unrecorded. The mean intraoperative lymph node harvest was 20 (standard deviation: 7) in those cases with a primary oesophageal malignancy (*n*=149). Resection margins were deemed positive when the tumour was present within <1mm from the cut edge. The resection margin was positive in 46/149 cases and longitudinal margins were involved in 4/149 cases.

Overall, 159 complications were recorded in 89 patients (57%), 100 (63%) of which were considered to be minor and 59 (37%) major (Table 3). Respiratory complications accounted for 47% of the total complications encountered. The majority of pneumothoraces and pleural effusions coincided with the occurrence of other complications. Eleven patients (7%) required reoperation (Table 4); one patient returned to theatre twice (once for resection of a necrotic tube and a second time for bleeding at the cervical oesophagostomy site). No complications occurred relating to either intraoperative or postoperative flexible gastroscopy performed by the surgical team.

Four patients died during their inpatient stay. The overall inpatient mortality rate was 2.6%. One patient died on day 10 after a massive intraoperative haemorrhage following iatrogenic damage to the aorta. A further patient died on day 12 following a myocardial infarction and anastomotic leak. Another died on day 70 of multiple organ failure following major gastrointestinal bleeding. The fourth patient died on day 100 following gastric tube necrosis and multiple episodes of chest sepsis.

Gastric tube complications

There were 16 anastomotic leaks in this series. Eight were classified as radiological only with no clinical sequelae. Of the eight clinical anastomotic leaks, one was associated with a necrotic gastric tube requiring reoperation and another three also required reoperation.

Four patients (2.6%) developed gastric tube necrosis (Table 5). All cases occurred in the first 73 patients, namely cases 8, 44, 59 and 73. Three cases presented on days 5–7 with a pleural effusion and sepsis. The diagnosis was made at endoscopy, where necrotic mucosa was seen but the gastric tube and anastomosis were intact. The fourth patient presented with an anastomotic leak on the fourth postoperative day. All four patients had a resection of the gastric tube with formation of a cervical oesophagostomy and placement of a feeding jejunostomy.

Of these four patients, one died as an inpatient on day 100 following several septic episodes and another died at home of general exhaustion 2 months following discharge on the 124th postoperative day. Of the two survivors, one underwent reconstruction using a colonic interposition graft after six months. The final patient declined any reconstructive surgery and remains disease free more than five years after his operation.

The aetiology of the gastric tube necrosis was identified in two cases as injury to the gastroepiploic arcade at the time of the initial operation. Another patient was found to

Table 5 Patients with gastric tube necrosis

Case number	Age / sex	Cause	Presentation	Diagnosis	Outcome	Other relevant information
7	73M	Nil noted	Sepsis, pleural effusion	Endoscopy (day 5)	Discharge day 47; deceased day 124	Heavy ex-smoker (>50 pack years), stopped 6 months prior to surgery
44	75M	Tight hiatus	Clinical leak	Thoracotomy (day 4)	Declined reconstruction; disease free	Cigar smoker (1/day)
59	60F	Injury to gastroepiploic arcade	Pleural effusion	Endoscopy (day 7)	Colonic interposition graft; disease recurrence 3.5 years	Heavy ex-smoker (>50 pack years), stopped 5 months prior to surgery; developed acute onset AF postoperatively
73	75M	Injury to gastroepiploic arcade	Sepsis	Endoscopy (day 5)	Endoscopy (day 5)	Pipe smoker; developed acute onset AF postoperatively

M = male; F = female; AF = atrial fibrillation

have the attached omentum impacted in the diaphragmatic hiatus, resulting in a cut-off point and necrosis of the intrathoracic conduit. In the remaining case, no identifiable cause for the necrosis was identified. All four patients had a positive smoking history, with two patients smoking up to the day of their resection and two who had stopped smoking shortly before their resections but had a pack-year history of >50 years.

The first 50 cases (so-called learning curve) were completed in 2 years. The gastric tube necrosis rate of the first 50 cases and that of cases 51–155 were 4% and 2% respectively (p=0.5948). The anastomotic leak rates in these two cohorts were 18% and 7% respectively (p=0.0457). The combined gastric tube necrosis and leak rate was significantly higher in the first 50 cases compared with the next 105 cases, at 22% and 10% respectively (p=0.0447).

Discussion

MIOs have become increasingly popular, with the first fully minimally invasive procedure being completed in 1999.[7] The initial concerns regarding oncological parity when compared with an open technique have now been largely discredited. In 2007 Gemmill and McCulloch reviewed 23 studies covering a total of 1,398 patients undergoing MIOs.[11] They found that the overall 30-day inpatient mortality rate was 2.3%, with a combined major and minor morbidity rate of 46.2%. In a more recent systematic review, Verhage *et al* combined the data from ten case-controlled studies and one systematic review, and found that minimally invasive oesophagectomy was associated with a decreased blood loss (312ml vs 577ml), a reduction in critical care stay (4.5 vs 7.6 days) and total inpatient stay (14.9 vs 19.6 days), and a reduced complication rate of 43.8% compared with 60.4% in the open group.[2] The mean lymph node retrieval was increased at 23.8 versus 20.2.

The incidence of ischaemia and necrosis of pedicled grafts has been reported extensively in the plastic surgery literature with the main patient risk factors being smoking, age, obesity and irradiation, and the main technical factors being arterial supply, venous drainage and tension in the graft.[12,13] Ischaemic failure of the gastric tube (also a pedicled graft) resulting in complications such as anastomotic leakage or frank necrosis is a well recognised problem with both open and laparoscopic oesophagectomy. Some authors have also linked the development of anastomotic strictures to gastric tube ischaemia.[14]

Wormuth and Heitmiller found that the average rates of ischaemic complications for stomach, colon and jejunal conduits after oesophagectomy were 3.2%, 5.1% and 4.2% respectively.[15] They also stated that conduit ischaemia was influenced by operative technique, length of conduit and the site of the proximal anastomosis, with the neck anastomosis more likely to suffer ischaemia. In a case series of 47 patients, Scheepers *et al* reported the rate of ischaemic complications of the anastomosis following MIO as 23%.[16] In the third National Oesophago-Gastric Cancer Audit in the UK, the anastomotic leak rate after MIO was 10.6% compared with the open group's 7.8%.[1] In a case series by Berrisford *et al*, the authors reported on 70 MIOs, with 9 patients (12.9%) suffering gastric conduit complications.[17]

Several authors have tried to solve the problem of gastric tube ischaemia after laparoscopic oesophagectomy. In an experimental study in pigs, significant improvement in gastric tube blood flow was found following intravenous administration of unmodified prostaglandin E_1 (PGE1) and lipo-PGE1 (p<0.01).[18] In a study of gastric ischaemic preconditioning, Beck *et al* showed in animal models that if the short gastric and left gastric vessels were ligated three weeks prior to oesophagectomy, formation of the gastric tube resulted in the gastric blood flow falling to only 60% of the baseline compared with 16% in those who were not preconditioned (p=0.07).[19] Hölscher *et al* described their study of 83 cases where laparoscopic preconditioning of the stomach was undertaken at an average of 4.3 days prior to the definitive procedure.[5] They showed a leak rate of 5%, a major morbidity rate of 13% and a 90-day mortality of 0%, and they identified no cases of tube necrosis. They felt that laparoscopic gastric preconditioning reduced patient morbidity and mortality.

Another suggestion has been the performance of extracorporeal gastric tube formation through a mini-laparoto-

my.[9] This may mean that the benefit of reduced perioperative pain with minimally invasive surgery is lost and it may also impact adversely on the respiratory complication rate.

Our retrospective study of MIO from 2005 to 2011 shows results comparable with other similar studies in that our mean operating time was 280 minutes, the median inpatient stay was 14 days, the inpatient mortality rate was 2.6% and the total patient complication rate was 57%. Of the 11 reoperations in the series, 7 were for anastomotic leaks or gastric tube necrosis. Not all anastomotic leaks are ischaemic in nature and ischaemia of the gastric tube does not invariably lead to a leak. In our series, three patients were reoperated on for clinical leaks but no ischaemia of the gastric tube was documented whereas of the four patients with documented tube ischaemia/necrosis, only one presented with a leak.

The subclinical conduit ischaemia rate is likely to be significantly higher but as we did not perform routine postoperative gastroscopies, it remains unknown. Because we also did not perform radiological investigation of the anastomosis routinely after the first 50 cases, we may have underestimated the total leak rate. However, this is not of clinical relevance.

The 4 cases of gastric tube necrosis in our MIO series occurred within the first 73 cases performed. The length of a learning curve varies significantly between different procedures. The learning curve also depends on whether the procedure is learnt in a mentoring or pioneering type model.

For example, the introduction of robot assisted urological surgery has sparked discussion regarding its steep learning curve, with Moreno Sierra *et al* stating that there was a consensus among 8 out of 13 urology teams that the learning curve lasted around 20–25 cases.[20] Kye *et al* evaluated the learning curve faced in laparoscopic right-sided colon cancer surgery, and concluded that the 18th case in a first-generation colorectal surgeon and the 8th case in a laparoscopically trained surgeon were the overall peak points in the learning curves.[21] AUGIS suggests a learning curve of around 20–50 cases for MIO,[7] and this was supported by our own data, which showed a significant reduction in the overall gastric tube complications after the first 50 cases.

Conclusions

Many patients undergoing oesophagectomy are elderly and have a smoking history, which increases the risk of graft ischaemic complications. Furthermore, gastric tube complications such as necrosis and leaks are increased during the learning curve of MIO and immediate pedicled gastric tube reconstruction. Meticulous attention to preserving the epiploic arterial blood supply, venous drainage, optimal sizing of the hiatus and avoiding tension in the tube are important factors in preventing ischaemia. Two stage gastric ischaemic preconditioning or open extracorporeal creation of the gastric tube may not be necessary. For those surgeons embarking on MIO, learning the operation in a mentoring model may reduce the length of the learning curve, thereby allowing them to achieve similar results to their open surgery in a shorter time frame.

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