Surg Endosc (2011) 25:2071–2083
DOI 10.1007/s00464-010-1511-2

REVIEWS

Minimally invasive oesophagectomy: current status and future direction

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Received: 24 February 2010 / Accepted: 26 July 2010 / Published online: 7 February 2011

Abstract
Background Oesophagectomy is one of the most challenging surgeries. Potential for morbidity and mortality is high. Minimally invasive techniques have been introduced in an attempt to reduce postoperative complications and recovery times. Debate continues over whether these techniques are beneficial to morbidity and whether oncological resection is compromised. This review article will analyse the different techniques employed in minimally invasive oesophagectomy (MIO) and critically evaluate commonly reported outcome measures from the available literature.
Methods Medline, Embase, Science Citation Index, Current Contents, and PubMed databases were used to search English language articles published on MIO. Thirty-one articles underwent thorough analysis and the data were tabulated where appropriate. To date, only level III evidence exists. Where appropriate, comparisons are made with a meta-analysis on open oesophagectomy.
Results Positive aspects of MIO include at least comparable postoperative recovery data and oncological resection measures to open surgery. Intensive care unit requirements are lower, as is duration of inpatient stay. Respiratory morbidity varies. Negative aspects include increased technical skill of the surgeon and increased equipment requirements, increased operative time and limitation with respect to local advancement of cancer. With increasing individual experience, improvements in outcome measures and the amenability of this approach to increasing neoplastic advancement has been shown.
Conclusion MIO has outcome measures at least as comparable to open oesophagectomy in the setting of benign and nonlocally advanced cancer. Transthoracic oesophagectomy provides superior exposure to the thoracic oesophagus compared to the transhiatal approach and is currently preferred. No multicentre randomised controlled trials exist or are likely to come into fruition. As with all surgery, careful patient selection is required for optimal results from MIO.

Keywords Oesophagectomy · Laparoscopy · Oesophageal cancer · Retrospective studies · Prospective studies · Comparative studies · Patient outcome · Intraoperative complications · Postoperative complications · Hospitalisation · Human

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Surgical resection and replacement of the neoplastic oesophagus remains the definite therapeutic mode in order to achieve cure. Other indications for operative intervention include Barrett's oesophagus with high-grade dysplasia and benign disease refractory to medical or endoscopic treatment. Irrespective of aetiology, oesophagectomy has long been respected as one of the most challenging surgeries, with the combination of oesophageal anatomy and patient demographics giving a high potential for both morbidity and mortality. Recently, larger centres have introduced minimally invasive techniques in an attempt to reduce postoperative complications and recovery times. Since the advent of minimally invasive oesophagectomy (MIO) over 15 years ago, debate has continued over whether laparoscopic techniques are actually beneficial to morbidity, and, further still, whether oncological resection is compromised. This review article analyses the different techniques employed in MIO and critically evaluates the commonly reported outcome measures from available literature.

Materials and methods

An electronic search for articles on the subject of laparoscopic oesophagectomy was performed through the Medline, Embase, Science Citation Index, Current Contents, and PubMed databases. The search strategy involved combining all of the available literature on the approach (i.e., minimally invasive) with operation type (i.e., oesophagectomy) for the disease process (i.e., oesophageal cancer/neoplasm). Keywords used with respect to approach were *laparoscopy* (MeSH terms, includes *laparoscopic*); *minimally* AND *invasive*; *minimally* AND *invasive* AND *surgery* (MeSH terms) OR *operative* OR *procedures* OR *operative procedures.* Keywords used with respect to the operation type were *esophagectomy* (MeSH term); *oesophagectomy* (United Kingdom spelling). Keywords used with respect to disease process were *neoplasm* (MeSH terms); *cancer.* Further searches using keywords for operation subtypes (*Ivor-Lewis; three-stage (o)esophagectomy; transhiatal*) did not reveal any further articles. Non-English articles, articles pertaining only to benign processes, and individual case reports were excluded. To date no randomised controlled trials exist; the available literature is limited to level III-2 evidence. All available case series and reports on MIO for oesophageal cancer were included. The minimally invasive techniques and reported data were analysed, and from this a selection of commonly recognised outcome measures was generated. Following the definition of the important outcome measures, the studies were separated into single-arm observational studies and comparative studies and also delineated by operative approach and method of data collection (prospective versus retrospective). Data from case series with 15 or more patients were included for data tabulation. Some overlap of data was observed and was subsequently accounted for. Where between-study homogeneity was clear, for example, multiple-case series reporting a purely minimally invasive approach to both abdominal and thoracic components, descriptive statistics were acquired using an electronic statistics package (SPSS Statistics 17.0, SPSS Inc.). Using the available data, we report the history of MIO, discuss reported outcome measures, present thinking on current best practice, and also postulate the future of oesophagectomy. Where appropriate, comparisons were made with a meta-analysis by Hulscher et al. [1] comparing open transhiatal versus open transthoracic oesophagectomy.

Results

Thirty-one suitable articles [1], consisting of mainly prospective and retrospective studies, were identified. Seven series [25–31] directly compared open oesophagectomy versus MIO; two of these [27, 28] were performed prospectively. Review of 30 of the identified papers [2–31] revealed three main groups of common outcome measures: operative data, morbidity and mortality data, and oncological resection data. Main operative outcome measures were defined as total operative time, conversion rate, and blood loss. Morbidity data was defined by early and late complication rates, duration of intensive care requirement, and total hospital stay. Complications of particular importance were also recorded and comprised anastomotic leaks, chylothorax, and specific respiratory morbidity. Perioperative mortality was defined by death within 30 days from the procedure. Oncological outcome measures were pathological disease stage, margin involvement, local recurrence, lymph node yield, and overall survival. Neoadjuvant treatment numbers were included for each study.

Twenty five case series containing 15 or more patients were identified for data tabulation (Tables 1, 2, 3, 4, 5, 6, 7, 8). Operative time was recorded in 94% of the single-arm observational studies and 86% of the comparative studies (only one comparison study did not [27]). All 25 studies included for data analysis reported important outcome measures in percentages as follows: blood loss 81%, incidence of anastomotic leak 68%, incidence of respiratory morbidity 92%, incidence of chylothorax 96%, duration of ICU stay 76%, duration of overall hospital stay 92%, 30-day operative mortality 100%, extent of oncological resection (positive margins/local recurrence and/or lymph node yield) 88%, survival at (variable) mean follow-up 72%.

Twelve case series [2–5, 8, 9, 13, 15, 25, 28, 29, 31] directly reported results for completely minimally invasive transthoracic oesophagectomy regardless of abdominal component and anastomosis site. Selected results were as follows (reported figures were weighted according to study sample size, n is the number of studies included in the calculation): mean operation time 312 min (range = 220–476 min) ($n = 11$); median blood loss 425 ml

Table 1 Operative data—single-centre cohort studies

Author/year	Study type	Patients n (%)	Abdominal component	Thoracic component	Anastomosis site	Operative time (min)	Conversions n (%)	Blood loss (ml)
Martin/05 [2]	PST	36	Open or MI (hand-assisted)	MI	Cervical	263	2	200
Liebman/05 [3]	PST	25	MI	MI	Cervical	330	2 (8)	300
Suzuki/05 [4]	PST (not stated)	19	MI (hand-assisted)	MI	Cervical	476	0	343
Palanivelu/06 [5]	PST	130	MI	MI	Cervical	220	0	180
Bottger/06 [6]	PST	25	MI—transhiatal, 3-stage	MI 12, open 4 (3-stage)	Cervical	165, 300	0	300
Godiris-Petit/06 [7]	PST	25	MI	Open	Thoracic	368	1 (4)	<100
Berrisford/08 [8]	PST	77	MI	MI	Cervical	413	1 (1)	425
Robertson/95 [9]	RST	17	Open	MI	Thoracic	330	5 (29)	N/R
Kawahara/98 [11]	RST	23	Open	MI	Cervical	111 (thoracic)	0	163
Nguyen/03 [13]	RST	46	MI	MI	Both	350	2	279
Luketich/03 [14]	RST	222	MI—transhiatal 8, 3-stage 214	MI	Cervical	N/R	16 (7.2)	N/R
Collins/05 [15]	RST	25	MI	MI	Cervical	350	2	200
Espat/04 [19]	RST	15	MI—transhiatal (robot-assisted)	N/A	Cervical	274	0	50
Palanivelu/05 [20]	PST	32	MI—transhiatal	N/A	None	200	0	150
Avital/05 [21]	RST	22	MI—transhiatal	N/A	Cervical	380	1 (5)	220
Bann/05 [22]	RST	20	MI—transhiatal	N/A	Cervical	415	2 (10)	300
Tinoco/07 [23]	RST	78	MI—transhiatal	N/A	Cervical	153 (lap component)	5 (6)	N/R
Sanders/07 [24]	RST	18	MI—transhiatal	N/A	Cervical	300	2 (11)	N/R

MI minimally invasive, *N/A* not applicable, *N/R* not recorded, *PST* prospective series, *RST* retrospective series

(range = 65–700 ml) ($n = 11$); median incidence of anastomotic leak 5.5% (range = 0–53.0%) ($n = 9$); median incidence of respiratory complications 31.7% (range = 0–223.5%) ($n = 11$); median incidence of chylothorax 5.2% (range = 2.2–26.7%) ($n = 12$); median duration of ICU stay 1 day (range = 1–19 days) ($n = 10$); median duration of hospital stay 13 days (range = 7–16 days) ($n = 12$); median 30-day mortality 1.0% (range = 0–6.5%) ($n = 12$).

Nine case series [3, 5, 8, 13, 15, 25, 28, 29, 31] directly reported results on a purely minimally invasive approach to transthoracic oesophagectomy. Selected results from these series were as follows: median operation time 330 min (range = 220-413 min) ($n = 9$); median blood loss 279 ml (range = 65–700 ml) ($n = 9$); median incidence of anastomotic leak 5.6% (range = 0–40.0%) ($n = 7$); median incidence of respiratory complications 7.8% (range = 3.1–60.0%) ($n = 9$); median incidence of chylothorax 3.0% (range = 1.0–4.0%) ($n = 9$); median duration of ICU stay 1 day (range = 1–19 days) ($n = 8$); median duration of hospital stay 9 days (range = 7–14 days) ($n = 9$); median 30-day mortality 1.0% (range = 0–3%) ($n = 9$).

Five case series [20–22, 24, 29] directly reported results on a purely minimally invasive transhiatal technique. Selected results from these series were as follows: mean operation time 305 min (range = 200–415 min) ($n = 5$); median blood loss 220 ml (range = 150–325 ml) ($n = 4$); median incidence of anastomotic leak 8.0% (range = 7.7–29.2%) ($n = 3$); median incidence of respiratory complications 9.0% (range = 8.3–25.0%) ($n = 4$); median incidence of chylothorax 3.1% (range = 2.6–20.8%) ($n = 5$), median duration of ICU stay 1 day (range = 1–5 days) ($n = 3$); median duration of hospital stay 12 days (range = 7–17 days) ($n = 5$); median 30-day mortality 0% (range = 0–4.6%) ($n = 5$).

Techniques of minimally invasive oesophagectomy

Two main techniques have been described for oesophageal resection; transthoracic oesophagectomy and transhiatal oesophagectomy. In total, three sites of exposure can be utilised in oesophagectomy: the abdomen, the thorax, and the neck. Transthoracic (Ivor-Lewis) resection involves direct, and separate, abdominal and transthoracic access

Table 2 Operative data—comparative series

Author/year	Study type	Patients *n* (%)	Abdominal component	Thoracic component	Anastomosis site	Operative time (min)	Conversion *n* (%)	Blood loss (ml)
Nguyen/00 [25]	RST comparison	18	MI	MI	Cervical	364	0	297
		16	Open	Open	Both	437	N/A	1046
		20	Open—transhiatal	None	Cervical	391	N/A	1142
Bresadola/06 [26]	RST comparison	14	MI—transhiatal, thoracoscopic	Open	Cervical	423	0	N/R
		14	Open	Open	Cervical	359	N/A	N/R
Braghetto/06 [27]	PST comparison	60 (36.1)		Open	Cervical	N/R	N/A	N/R
		59 (35.5)	Open—transhiatal	None	Cervical	N/R	N/A	N/R
		47 (22.3)	MI	MI	Cervical	N/R	N/R	N/R
Smithers/07 [28]	PST comparison	23	MI	MI	Cervical	330	2 (9)	300
		309	Open	MI	Cervical	300	10 (8.8)	600
		114	Open	Open	Thoracic	285	N/A	400
Dapri/07 [29]	RST comparison	24	MI—transhiatal	None	Both	300	0	325
		15	MI	MI	Cervical	370	1	700
Fabian/07 [30]	RST comparison	22	MI	Both	Both	333	1 (5)	178
		43	Open	Open	Both	270	N/A	356
Fabian/08 [31]	RST comparison	21	MI	MI—prone	Cervical	330	3 (9)—combined	65
		11	MI	MI—decubitus	Cervical	375	3 (9)—combined	85

MI minimally invasive, *N/A* not applicable, *N/R* not recorded, *PST* prospective series, *RST* retrospective series

with or without dissection at the cervical oesophagus depending on the site of anastomosis. Transhiatal oesophagectomy negates direct access to the mediastinum through the thoracic wall and also may require dissection of the cervical oesophagus depending on anastomosis site. The first described techniques for MIO were in transhiatal procedures by DePaula et al. [32] in Brazil and by Swanstrom et al. [10] in North America. Subsequent to these, video assistance was employed for transthoracic oesophagectomy. As skills and technology have developed, laparoscopy has become increasingly successful for the abdominal component of Ivor-Lewis oesophageal resection. Gastric preconditioning, whereby the stomach is mobilised on the right gastric arterial pedicle to assess conduit viability prior to the resection surgery, is not mentioned by the proponents of MIO.

Transhiatal oesophagectomy

As described, minimally invasive transhiatal oesophagectomy was developed first and negates the need for transthoracic exposure in an attempt to reduce postoperative pulmonary complications. Most proponents of this procedure use 5-port laparoscopy with the patient in varying degrees of anti-Trendelenburg position. Although techniques continue to be refined, most proponents describe operator positioning between the patient's legs, with the camera holder and instrument nurse to the patient's left side and the second assistant to the right (Fig. 1). A consensus on abdominal port placement is provided in Fig. 2. All oncological oesophagectomies commence with a thorough general inspection. The stomach may be mobilised before or after oesophageal dissection. Irrespective of the order, all lymph nodes and fatty tissue from the coeliac axis and common hepatic and splenic arteries are cleared via an incision through the lesser omentum; these are then swept into the resection specimen. Oesophageal dissection begins at the crura using harmonic shears with en bloc excision of any locally involved tissue. The posterior mediastinum is entered and adequate circumferential mobilisation of the oesophagus is achieved by a combination of blunt and sharp harmonic dissection. A tape may be passed around the oesophagus to aid retraction, although some authors [20] avoid this because of concern over tumour spill. A proximal margin of at least 5 cm is the goal. The stomach is mobilised in the usual fashion with preservation of the right gastric artery and right gastroepiploic vascular arcade. Although intrathoracic anastomosis has been described for the transhiatal approach [29], this anastomosis site is generally avoided with preference for a cervical anastomosis following gastric pull-up. To achieve this, open access and dissection are employed and the proximal

Table 3 Morbidity and mortality—single-centre cohort studies

Author/year	Patients *n*	Approach	Early complications *n* (%)	Late complications *n* (%)	ICU stay (days)	Hospital stay (days)	30-day mortality *n* (%)
Martin/05 [2]	36	Transthoracic	15 (42)	1 (3)	1	16	2 (6)
Liebman/05 [3]	25	Transthoracic	16 (64)	1 (4)	19	11	0 (1 at 47 days)
Suzuki/05 [4]	19	Transthoracic	3 (16)	0	1	10	0
Palanivelu/06 [5]	130	Transthoracic	27 (20.8)	1 (0.8)	1	8	2 (1.5)
Bottger/06 [6]	25	Transthoracic	3 (12)	0	1.5	10	0
Godiris-Petit/06 [7]	25	Transthoracic	15 (60)	2 (8)	1	18	1 (4)
Berrisford/08 [8]	77	Transthoracic	33 (47)	3 (4)	6.5 (emergent only)	13	1 (1)
Robertson/95 [9]	17	Transthoracic	35 (207)	0	1	12	1 (6)
Kawahara/98 [11]	23	Transthoracic	9 (39)	1 (4)	0	26	0
Nguyen/03 [13]	46	Transthoracic	(27)	0	2	8	(4)
Luketich/03 [14]	222	MI—transhiatal 8, 3-stage 214	124 (55.9) (27.3)	4 (1.8)	1	7	3 (1)
Collins/05 [15]	25	Transthoracic	20 (80)	1 (4)	1	9	1 (4)
Espat/04 [19]	15	Transhiatal (robot-assisted)	N/R	N/R	1	N/R	0
Palanivelu/05 [20]	32	Transhiatal	3 (9)	N/R	1	7	0
Avital/05 [21]	22	Transhiatal	11 (50)	0	N/R	8	1 (5)
Bann/05 [22]	20	Transhiatal	15 (75)	0	1	17	0 (1 at 34 days)
Tinoco/07 [23]	78	Transhiatal	35 (45)	0	N/R	6.9	4 (6)
Sanders/07 [24]	18	Transhiatal	22 (122)	1 (6)	N/R	15	0

Table 4 Morbidity and mortality—comparative studies

Author/year	Patients *n* (%)	Approach	Early complications *n* (%)	Late complications *n* (%)	ICU stay (days)	Hospital stay (days)	30-day mortality *n* (%)
Nguyen/00 [25]	18	MI	6 (33)	0–1 (6) chylous ascites	6.1	11.3	0
	16	Open	8 (50)	0	9.9	23	0
	20	Open—transhiatal	11 (55)	0	11.1	22.3	0 (1 at 70 days)
Bresadola/06 [26]	14	MI—transhiatal, thoracoscopic	5 (36)	3 (21)	3.4	16.4	0
	14	Open	5 (36)	1 (7)	3.8	22.3	0
Braghetto/06 [27]	60 (36.1)	Open	34 (57)	0	N/R	N/R	7 (12)
	59 (35.5)	Open—transhiatal	33 (55)	0	N/R	N/R	6 (10)
	47 (22.3)	MI	14 (30)	1 (13)	N/R	N/R	3 (6)
Smithers/07 [28]	23	MI	14 (61)	N/R	1	11	0
	114	Open and MI—thoracoscopic	193 (67)	N/R	1	14	3 (2.6)
	309	Open	76 (62)	N/R	1	13	7 (2.3)
Dapri/07 [29]	24	Open—transhiatal	13 (54)	0	5	12	0
	15	MI	13 (87)	0	5	14	0
Fabian/07 [30]	22	MI	15 (68)	0	N/R	9.5	1 (5)
	43	Open	31 (72)	2 (5)	N/R	11	4 (9)
	11	MI	6 (55)	1 (9)	N/R	9	0
Fabian 08 (31)	21	MI	10 (48)	0	N/R	10	1 (5)
	11	MI	6 (55)	1 (9)	N/R	9	0

Table 5 Complications—single-centre cohort studies

Author/year	Patients *n*	Approach	Anastomotic leaks *n* (%)	Respiratory complications *n* (%)	Specific respiratory complications	Chylothorax *n* (%)
Martin/05 [2]	36	Transthoracic	2 (6)	2 (6)	Pneumonia, ARDS	7 (19)
Liebman/05 [3]	25	Transthoracic	0	15 (60)	Pneumonia, pleural effusion, atelectasis, pneumonthorax	2 (8)
Suzuki/05 [4]	19	Transthoracic	1 (5)	0	N/A	1 (5)
Palanivelu/06 [5]	130	Transthoracic	N/R	4 (3)	Pneumonia, ards, pleural effusion	3 (2.3)
Bottger/06 [6]	25	Transthoracic	2 (8)	1 (11)	Gastric-bronchial fistula	3 (12)
Godiris-Petit/06 [7]	25	Transthoracic	N/R	11 (44)	Pneumoia, ARDS, pneumothorax, pleuritis	2 (8)
Berrisford/08 [8]	77	Transthoracic	N/R	6 (9)	Pneumonia, respiratory failure	3 (4)
Robertson/95 [9]	17	Transthoracic	9 (53)	38 (224)	Pneumonia, pneumothorax, pleural effusion, empyema	3 (18)
Kawahara/98 [11]	23	Transthoracic	N/R	2 (9)	Pneumonia	1 (4)
Nguyen/03 [13]	46	Transthoracic	2 (4)	4 (9)	Pneumonia, pleural effusion, gastric-tracheal fistula	1 (2)
Luketich/03 [14]	222	Transthoracic 214, transhiatal 8	26 (11.7)	45 (20.3)	Pneumonia, ARDS, pleural effusion, atelectasis	7 (3.2)
Collins/05 [15]	25	Transthoracic	6 (24)	8 (32)	Pneumonia, atelectasis, pleural effusion, empyema	3 (12)
Espat/04 [19]	15	Transhiatal (Robot-assisted)	N/R	N/R	N/A	N/R
Palanivelu/05 [20]	32	Transhiatal	N/R	N/R	N/A	1 (3)
Avital/05 [21]	22	Transhiatal	3 (14)	5 (23)	Pneumonia, atelectasis	1 (5)
Bann/05 [22]	20	Transhiatal	N/R	5 (25)	Pneumonia, atelectasis	2 (10)
Tinoco/07 [23]	78	Transhiatal	10 (13)	14 (18)	Pneumonia, pleural effusion, pneumothorax, empyema	10 (13)
Sanders/07 [24]	18	Transhiatal	6 (33)	7 (39)	Pneumonia, atelectasis	2 (11)

oesophagus is divided using a linear stapler. After delivery of the gastric conduit into the neck, cervical anastomosis is achieved by either a hand-sewn interrupted technique or stapler. In the event of any pleural breach, mediastinal drains are placed, and prior to closure a feeding jejunostomy is usually sited.

Transthoracic oesophagectomy

Minimally invasive transthoracic oesophagectomy involves two or three stages depending on the site of oesophageal anastomosis, and it has traditionally been felt that it offers superior oncological resection when compared to the transhiatal approach. Access to the abdomen and the cervical area is generally achieved with the patient in the anti-Trendelenburg position, whereas thoracoscopic access is better with the lateral or prone position. Because of the subsequent need for intraoperative repositioning, the order by which the transthoracic technique is achieved tends to depend on the site of anastomosis. For intrathoracic anastomosis, it seems logical to fully complete the abdominal component of the operation prior to repositioning for thoracoscopic dissection and anastomosis, thus avoiding the need for further unnecessary movement of the patient. Likewise, in the situation of cervical anastomosis, completing the thoracoscopic dissection prior to the abdominal and cervical components achieves the same economy of movement.

Where cervical anastomosis is to be performed, the first stage of the operation varies among authors; some prefer initial dissection in the abdomen, whilst others prefer initial oesophageal mobilisation in the thorax. As described above, the latter approach reduces the required amount of intraoperative repositioning. Irrespective of this, the abdominal component of the procedure proceeds in a fairly universal way. The anti-Trendelenburg position is acquired and a 5-port laparoscopy is set up, not dissimilar in pattern to that of the transhiatal procedure described above (Figs. 1, 2); however, the operator usually stands on the patient's right side instead of between the legs. The primary assistant stands on the patient's left with the monitor placed at the patient's head end. Stomach is most commonly used for conduit, but colon may be required in the situation of distal tumour spread or previous gastrectomy.

Table 6 Complications—comparative studies

Authors	Patients n (%)	Approach	Anastomotic leaks n (%)	Respiratory complications n (%)	Specific respiratory complications	Chylothorax n (%)
Nguyen/00 [25]	18	MI	1 (6)	3 (17)	Gastric-bronchial fistula, respiratory failure	2 (11)
	16	Open	0	3 (19)	Respiratory failure	2 (12)
	20	Open—transhiatal	0	3 (15)	Respiratory failure	2 (10)
Bresadola/06 [26]	14	MI—transhiatal, thoracoscopic	2 (14)	1 (7)	Respiratory failure	0
	14	Open	1 (7)	2 (14)	Respiratory failure	0
Braghetto/06 [27]	60 (36.1)	Open	37 (62)	17 (28)	Pneumonia, pleural effusion	13 (22)
	59 (35.5)	Open—transhiatal	35 (59)	18 (31)	Pneumonia, pleural effusion	13 (22)
	47 (22.3)	MI	18 (38)	9 (19)	Pneumonia, pleural effusion	4 (9)
Smithers/07 [28]	23	MI	4 (17)	8 (34)	Pneumonia, pleural effusion	1 (4)
	309	Open and MI—thoracoscopic	17 (5.5)	98 (31.7)	Pneumonia, pleural effusion	16 (5)
	114	Open	10 (8.7)	44 (38.6)	Pneumonia, pleural effusion	7 (6.1)
Dapri/07 [29]	24	Open—transhiatal	(29)	2 (8)	Pneumonia, pneumothorax	5 (28)
	15	MI	6 (40)	1 (7)	Respiratory failure	4 (27)
Fabian/07 [30]	22	MI	1 (5)	6 (27)	Respiratory failure, pneumonia, reintubation	3 (14)
	43	Open	2 (5)	41 (95)	Respiratory failure, pneumonia, reintubation	3 (7)
Fabian/08 [31]	21	MI	N/R	3 (12)	Pneumonia, respiratory failure	1 (4)
	11	MI	N/R	2 (18)	Pneumonia, respiratory failure	2 (18)

For gastric conduit, mobilisation of the stomach is performed as per the transhiatal approach. Kocherisation of the duodenum is required to mobilise the pylorus to the oesophageal hiatus. Dissection of the lower oesophagus can be achieved as far as the extent of direct vision. The gastric conduit is created using multiple loads of a linear cutting stapler, starting at the lesser curvature. Many operators do not complete transection of the pathologic specimen at this point as keeping this continuity later facilitates retraction of the conduit into the chest.

The thoracic component is performed with the patient in either a lateral or a prone position (Figs. 3, 4) to aid exposure of the mediastinal oesophagus. The prone position, in particular, places the oesophagus at the upper limit in the thorax and enables the right lung to fall away under gravity [12]. The clear disadvantages of the prone technique are the inherent practical issues of physically achieving such a position and the associated difficulty with airway management. There is little consensus on thoracic port placements, which are dependent on patient positioning. Single-lung ventilation is required. Where patients have not tolerated single-lung ventilation, low-pressure gas insufflation has been successfully employed. Dissection is achieved with ultrasonic shears, and manipulation of the oesophagus is aided by looping tape around its circumference from an early stage.

Following oesophageal mobilisation, the specimen can be manipulated and transected in the thorax, abdomen, or neck depending on disease site and surgeon's preference. Anastomosis sites and technique vary among authors. When an intrathoracic anastomosis is required, technique is particularly critical to reduce the risk of leak and its associated morbidity. All minimally invasive techniques for intrathoracic anastomosis describe use of a circular end-to-end stapler. The detachable anvil may be introduced into the proximal oesophagus via either abdomen or thorax, but extension of thoracic port sites is avoided where possible. Following ligature or clamp occlusion of the proximal margin of the specimen, the anvil is introduced into the proximal oesophagus via a transverse incision. Anvil anchorage is now necessary and has been regarded as a rate-limiting step. Two principal methods of anvil fixation are subsequently described: purse string and ligature techniques. The traditional method of purse string placement is time consuming in MIO and has led to the development of new instruments and techniques. The Endo-Stitch device (US Surgical), described by Misawa et al. [33], consists of a two-jawed endoscopic instrument with each jaw capable of holding a double-ended straight needle. Used on soft tissues, this instrument enables the placement of running or interrupted sutures more efficiently by one hand. The alternative Z-stitch technique,

Table 7 Oncological data—single-centre series

Author/year	Patients n (%)	Approach	Pathological tumour stage	Neoadjuvant therapy n (%)	Positive margins/ local recurrence n (%)	Lymph nodes	Survival (%) (follow-up period)
Martin/05 [2]	36	Transthoracic	II–IV	23 (68)	5 (14)/N/R	N/R	44 (4 yr)
Liebman/05 [3]	25	Transthoracic	0–III	8 (32)	4 (16)/4 (16)	17	32 mo (32 mo)
Suzuki/05 [4]	19	Transthoracic	0–Iva	5 (26)	0/0	N/R	N/R
Palanivelu/06 [5]	130	Transthoracic	I–III	1 (0.8)	N/R	18	75–18 (20 mo)
Bottger/06 [6]	25	Transthoracic	I–III	N/R	N/R (all tumours lower 1/3)	14, 23[a]	N/R
Godiris-Petit/06 [7]	25	Transthoracic	0–IV	5 (20)	0/2 (4)	12	56 (2 yr)
Berrisford/08 [8]	77	Transthoracic	0–IV	44 (68)	2 (3)/3 (4)	21	81 (2 yr)
Robertson/95 [9]	17	Transthoracic	II–III	0	2 (12)/5 (29)	7	59 (23 mo)
Kawahara/98 [11]	23	Transthoracic	0–IV	5 (28)	0/1 (4)	29	78 (15 mo)
Nguyen/03 [13]	46	Transthoracic	I–IV	23 (61)	0/N/R	10	57
Luketich/03 [14]	222	MI—transhiatal 8, 3-stage 214	0–III	36 (16)	N/R	N/R	20–95 (19 mo)
Collins/05 [15]	25	Transthoracic	0–IV	7 (28)	1 (4)/N/R	9	N/R
Espat/04 [19]	15	Transhiatal (robot-assisted)	II–III	0	0/1 (3)	19	67 (27 mo)
Palanivelu/05 [20]	32	Transhiatal	N/R	N/R	0/N/R	N/R	N/R
Avital/05 [21]	22	Transhiatal	I–III	N/R	N/R	14	61
Bann/05 [22]	20	Transhiatal	N/R	0	0/0	5	84 (11 mo)
Tinoco/07 [23]	78	Transhiatal	I–IV	N/R	N/R	N/R	19 (4 yr)
Sanders/07 [24]	18	Transhiatal	I–III	1 (6)	N/R	10	72 (13 mo)

[a] Study included 12 Pure MI Transhiatal resections, 14 lymph node harvest, and 4 Three-Stage resections with open thoracic component, 23 lymph node harvest

Table 8 Oncological data—comparative series

Authors	Patients n (%)	Approach	Pathological tumour stage	Neoadjuvant therapy n (%)	Positive margins/ local recurrence n (%)	Lymph nodes	Survival (%) (follow-up period)
Nguyen/00 [25]	18	MI	N/R	N/R	0/0	11	100 (3 mo)
	16	Open	N/R	N/R	1 (6)	6	N/R
	20	Open—transhiatal	N/R	N/R	1 (5)	7	N/R
Bresadola/06 [26]	14	MI—transhiatal, thoracoscopic	I-III	N/R	N/R	22	N/R
	14	Open	I-IV	N/R	N/R	19	N/R
Braghetto/06 [27]	60 (36.1)	Open	I-III	N/R	N/R	N/R	34
	59 (35.5)	Open—transhiatal	N/R	N/R	N/R	N/R	33
	47 (22.3)	MI	N/R	N/R	N/R	N/R	46
Smithers/07 [28]	23	MI	I-III	N/R	5 (20)/N/R	17	22 (5 yr)
	114	Open and MI—thoracoscopic	0-IV	N/R	21 (14)/N/R	16	41 (5 yr)
	309	Open	0-IV	N/R	42 (19)/N/R	17	16 (5 yr)
Dapri/07 [29]	24	Open—Transhiatal	I-IV	2 (8)	0/N/R	3	50
	15	MI	is-III	2 (13)	0/N/R	4	47
Fabian/07 [30]	22	MI	is-IV	9 (4.1)	0/N/R	15	N/R
	43	Open	is-IV	16 (37)	3 (6)/N/R	8	N/R
Fabian/08 [31]	21	MI	is-III	9 (43)	0/N/R	15.5	N/R
	11	MI	is-III	3 (27)	0/N/R	14.6	N/R

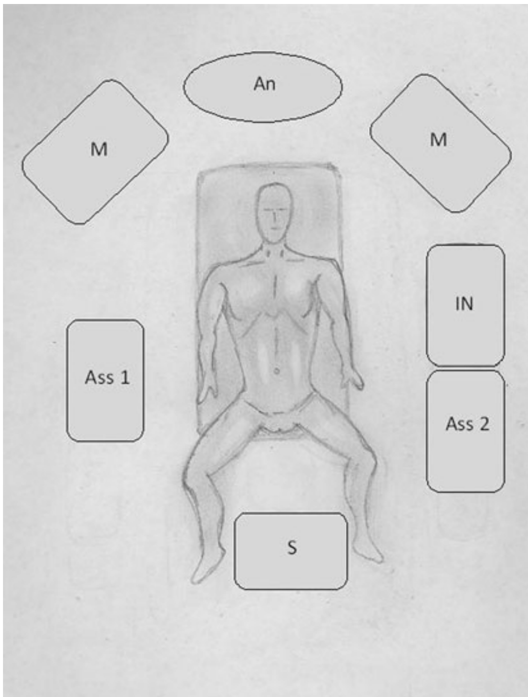

Fig. 1 General operating room layout for the laparoscopic abdominal component of MIO. An, anaesthetist; Ass 1, assistant 1; Ass 2, assistant 2; IN, instrument nurse; M, monitor; S, surgeon

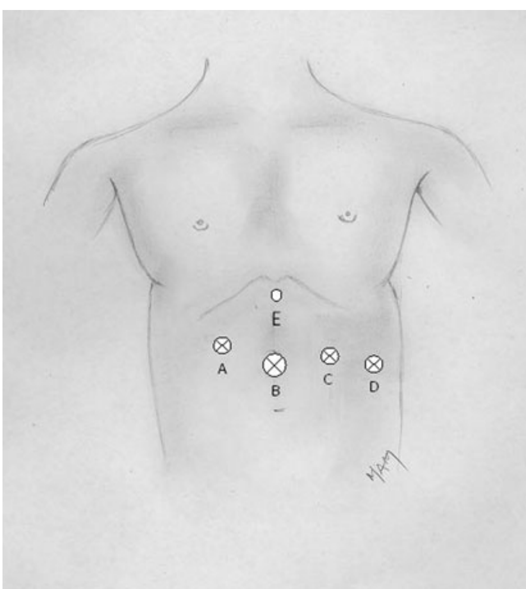

Fig. 2 Laparoscopic port site placement for abdominal part of MIO. *A*, *C*, *D* 5-mm ports. *B* 10-mm port

described by Thairu [34], utilises cross-firing of a linear stapler to create a 60° angle at the proximal oesophagus whilst the anvil is in situ. The smaller aperture associated with this technique enables a Z-stitch to suffice for anchorage. The ligature technique applies a principle first

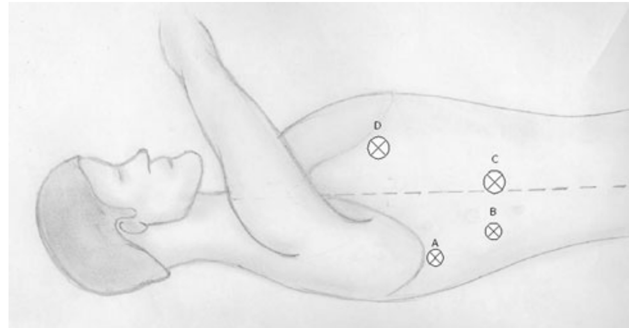

Fig. 3 Thoracoscopic port site placement for MIO: left lateral decubitus position. *A*, *B* 5-mm ports. C, D 10-mm ports

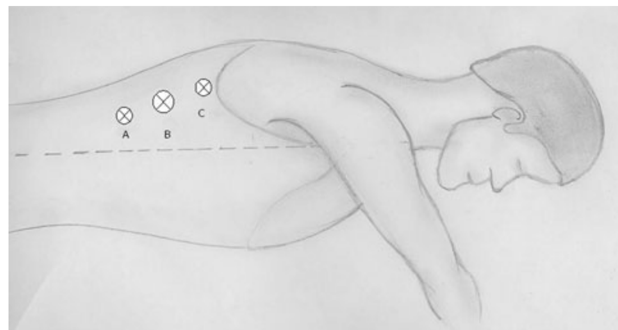

Fig. 4 Thoracoscopic port site placement for MIO: prone position. *A*, *C* 5-mm ports. *B* 10-mm port

reported by Allsop [35] in colorectal anastomoses and is described by Lee [36] in the setting of oesophagectomy. This method avoids purse string creation altogether by single ligature approximation of the oesophagus onto the purse string notch of the anvil. Once anvil placement and anchorage are achieved, the final specimen resection and oesophagogastric anastomosis are performed in a uniform manner. The specimen is delivered into the abdomen and divided distally with a linear stapler. Distal transverse gastrotomy enables introduction of the proximal circular stapler, which is then carefully advanced in a caudal direction until correctly positioned within the tubularised stomach and in apposition to the proximal oesophagus. The anvil and stapler are engaged and the anastomosis completed. A pleurally sited intercostal catheter can be placed for drainage.

Discussion

Open oesophagectomy utilising a transthoracic or transhiatal approach remains the gold standard treatment for benign and malignant conditions of the oesophagus. Both of these open approaches to oesophageal resection have been validated and a recent meta-analysis [1] suggests that they result in similar morbidity, mortality, and 5-year survival rates. Theoretically, respiratory morbidity should occur more frequently in the transthoracic approach but no statistically significant difference has been shown.

No randomised controlled trials currently exist for MIO, and it seems unlikely that any will be carried out given the known limitations of the procedure for locally advanced primary disease. This, in addition to the high dependence of MIO on advanced technical skill, has resulted in a slow acceptance of this technique as a valid or achievable standard of care. The available comparative data do suggest that MIO is as good as open oesophagectomy when performed by an appropriately skilled and experienced surgeon. Of particular note is the work of Luketich et al. [14, 37], who have reported the largest series of MIO (222 patients), albeit noncomparatively. Morbidity rates are at least comparable to open procedures in this series. Luketich's mortality rate of 1.3% is better than the mortality rate of 5.7% for transhiatal oesophagectomy (THO) and 9.2% for transthoracic oesophagectomy (TTO) reported in the meta-analysis by Hulscher et al. [1] on open oesophagectomy. It is generally accepted that outcome following open oesophagectomy is better when performed in high numbers by dedicated surgeons, and it is logical to extrapolate that theory for MIO. Even so, MIO has been reported by smaller centres with comparable outcome measures to open oesophagectomy. For example, Bann et al. [22] reported on a prospective series of 22 patients who underwent Ivor-Lewis MIO at a district general hospital in the United Kingdom with oncological resection and morbidity results comparable to those of open oesophagectomy. Review of the existing studies shows a number of commonly assessed outcome measures for morbidity and oncological resection which will now be addressed individually.

Operative data

Operative time

It is unanimously accepted that total operative time (Tables 1, 2) is longer for MIO than for open surgery and except for the limitation caused by local oncological stage, this remains the major drawback in MIO. As with all comparisons to open oesophagectomy, variability in study size and subsequently induced statistical error need to be considered, as does the inherent selection bias of patients more likely to have less advanced and therefore more easily resectable disease.

Blood loss

Blood loss is reported by most authors in this series, with the range of averages between 50 and 700 ml (Tables 1, 2). The study with the lowest blood loss was by Espat [19] in 2004, who used a robot-assisted transhiatal approach in 15 patients with no conversions. There are no other recorded studies using this technology in the literature, which is not surprising given that robot-assisted surgery still remains very much in the avant-garde and is inaccessible to the vast majority of institutions. Otherwise little solid comparative data to open surgery exists, but there is certainly no overwhelming evidence of any significant difference in haemorrhage between MIO and open oesophagectomy.

Morbidity and mortality

Anastomotic leakage

Anastomotic leak is one of the most feared complications in oesophagectomy surgery, with a historical mortality rate of 50%. The definition of anastomotic leak varies between authors although most in this series used radiographic findings, whether carried out as a routine or because of clinical suspicion. From our analysis, MIO leakage rate ranged between 2.2 and 52.9% (Tables 5, 6), which is at least comparable to the reported leakage rates for open oesophagectomy [1], where rates vary from 3 to 50%. The wide range of leakage rate reported following open oesophagectomy was addressed by Hulscher et al. [1] in their meta-analysis, and they concluded that this wide-ranging result was more a reflection of the problem with definition rather than true technical differences. There is no apparent difference between leakage rates in thoracic or cervical anastomosis following MIO. For open surgery, transhiatal operations with cervical anastomoses seem to produce almost twice the anastomotic leak compared to transthoracic operations, where a majority of anastomoses were made through the chest (13.6 vs. 7.2%) [1]. From our collated data this does not appear to be reflected in MIO. Irrespective of absolute leakage rate, thoracic leakage tends to result in higher morbidity than cervical leakage, and this should be considered in addition to absolute numbers.

Respiratory morbidity

Major morbidity results from open transthoracic access. The thoracotomy incision is painful and also exposes the lungs to atmospheric pressure for extended periods, increasing barotrauma risk. Open transhiatal techniques were first developed in an attempt to avoid thoracotomy, but the inherent element of blind resection in this technique raised some concern over the adequacy of oncological resection and led to the first minimally invasive thoracoscopic approaches. Analysis of respiratory complication rate, however, shows fairly underwhelming results when compared to open techniques. Analysis of the 12 case series that report results on a transthoracic approach [2–5, 8, 9, 13, 15, 25, 28, 29, 31] provides a weighted median respiratory complication rate of 31.7%, which is high compared to the published data on open oesophagectomy; the meta-analysis by Hulcher et al. [1] reports respiratory complication rates of 18.7% for open transthoracic surgery and 12.7% for open transhiatal oesophagectomy. This alarming result is, however, probably more reflective of variation in reporting than a true difference. The notable extreme in respiratory complication rate was observed in the retrospective review of 17 patients who underwent a two-stage oesophagectomy performed by Robertson et al. [9]. In this series radiographic evidence of atelectasis was included in the complication rate irrespective of the clinical picture and thus accounted for 76% of all patients alone. Analysis of the available series that reported results of a purely minimally invasive approach to both the abdominal and the thoracic component reveals more promising information, with a combined respiratory complication rate of 7.8%. The largest available series by Luketich [14] was not included in either of the above grouped case series because 8 of 222 patients underwent transhiatal oesophagectomy and could not be differentiated from the remaining 214. This series reports a 12.6% combined respiratory complication rate defined as pneumonia and/or acute respiratory distress syndrome (ARDS). Meta-analysis of the open technique by Hulscher et al. [1] grouped pulmonary complications together, including pulmonary embolus (PE) with pneumonia and ARDS. The addition of PE to the Luketich et al. [14] data results in a morbidity rate of 14% compared to 18.7% for open transthoracic and 12.7% for open transthoracic techniques. It should be noted that Luketich et al. preferred the improved access of a minimally invasive transthoracic approach and that their morbidity result is at least comparable to that of the open transhiatal technique but with the benefits of improved mediastinal exposure.

Postoperative intensive care requirements and hospital stay

Median duration of postoperative stay on the intensive care unit (ICU) following MIO is 1 day in the majority of studies (Tables 3, 4). Some postoperative care protocols following MIO did not involve planned admission to ICU at all. In a series of 77 patients who underwent minimally invasive transthoracic oesophagectomy, Berrisford et al. [8] used ward-based postoperative care with central venous monitoring. This approach resulted in a 14% emergency admission rate to the formal ICU, however, and median stay on the ICU in these patients was longer at 6.5 days. It remains to be proven whether the avoidance of routine admission to ICU following MIO is a safe or cost-effective practice.

Mortality

Thirty-day mortality rates following MIO vary between 0 to 5.9% (Tables 3, 4), which compares to the open transthoracic procedure mortality rate of 9.2% and open transhiatal procedure mortality rate of 7.2% described by Hulscher et al. [1] in their meta-analysis. Patient selection for surgery may well bias these results, but most proponents of MIO believe this technique to be superior to open surgery in patients with early disease.

Oncological resection

Since the advent of MIO, the adequacy of oncological resection compared to that of open surgery has been questioned. Important and commonly reported outcome measures are resection margins, lymph node numbers, overall disease stage, and long-term survival.

All potentially curative oncological resections require complete clearance of local disease and therefore clear resection margins (i.e., R0) of the primary tumour are subsequently of the utmost importance. During the initial development of MIO, only benign or early-stage malignant disease was considered, and for most proponents of MIO this still remains the case. This practice is based on the expert opinion of these surgeons that an open approach still provides better oncological clearance for locally advanced disease compared to MIO and that potential cure from this outweighs the known difference in morbidity risk. The range of final pathological stage following MIO for malignant disease does range from 0 to IV (Tables 7, 8). Where a pathological stage IV was reported, surgery was usually completed on palliative grounds or when previously undiagnosed metastatic spread could be concomitantly resected. It should also be remembered that stage migration [38] can bias analysis of pathological stage. This upstaging is based on the idea that a more extensive lymphatic dissection results in a higher probability of node positive disease being diagnosed. Stage migration will also result in a more favourable long-term outcome relative to pathological stage.

Where reported, MIO results in clear resection margins in the vast majority. Martin et al. [2] reported the highest rate of resection margin involvement in a study of 36 patients who underwent hybrid three-stage transthoracic oesophagectomy. The technique included thoracoscopic mobilisation of the mediastinal oesophagus and hand-assisted laparoscopy in 21 patients and open laparotomy in the remaining 15. Of all resections, five had involved margins. Two were found to have unresectable primary disease irrespective of approach and three had positive radial margins, none of whom had received neoadjuvant therapy. On this note, at least one study [11] revealed an excellent response of some tumours to neoadjuvant therapy with significant pathological downstaging and subsequent successful resection with minimally invasive techniques.

Even with open oesophagectomy, there is still debate as to the best approach for optimal lymph node dissection. Given this, we will not comment on comparative data between transhiatal and transthoracic minimally invasive techniques. Analysis of all articles that used minimally invasive techniques on ten or more patients provides a range of average lymph nodes sampled of between 5 and 29 (Tables 7, 8). Variations on the extent of lymphatic dissection for any approach to oesophagectomy do exist and will undoubtedly bias the quoted figures influencing overall staging via stage migration.

Survival

Long-term survival following MIO varies. This is largely due to the retrospective data collection in most of the existing studies. If reliable 3- and 5-year survival follow-up data were available, one would expect similar results compared to stage-equivalent patients who underwent open surgery where clear margins and "adequate" lymphatic clearance were achieved, but this is speculative.

Learning curve/progression

The best example of progression in MIO comes from Luketich et al. [14, 37], who have published serial data on their experience. The initial approach was with laparoscopic transhiatal oesophagectomy, which changed to a thoracoscopic transhiatal technique over time. The initial description was of 77 patients who underwent MIO between August 1996 and September 1999 [37]. This has now been extended to include data for a total of 222 patients [14], the largest single series of any experience with MIO. Median operative time for the first 20 cases was 450 min, which decreased to 270 min thereafter. Anastomotic leak rate from initial experience was 9%, which increased slightly to 11.7% over all 222 patients. As experience grew, the minor complication rate decreased and the major complication rate increased. Overall mortality rate for the 222 patients was 1.4%. Progressively more advanced disease has become amenable to MIO through this series and should be taken into account when considering these data.

Conclusions

For benign disease and oesophageal cancer of stage III or less, MIO appears to be at least as good as open techniques when performed by experienced surgeons in large centres. Trends show acceptable morbidity, improved postoperative recovery time, and adequate oncological resection for early malignant disease. The immediately obvious negative aspects of MIO are the experience requirement, the need for advanced minimally invasive skills and equipment, and the increased operative time. Morbidity following thoracoscopic and transhiatal MIO techniques is similar. Whilst the transhiatal approach requires less intraoperative positioning, access to the mediastinum via the hiatus is limited and may compromise the extent of oncological resection. Thoracoscopy provides improved exposure to the middle and upper oesophagus and thoracic lymph nodes. Although the oncological outcome data following transhiatal MIO is scarce and negates further objective comparison to the thoracoscopic technique, achieving long-term locoregional control is the primary goal in any cancer surgery. For this reason, thoracoscopic mobilisation of the oesophagus, with either an open or a laparoscopic abdominal component, is the currently preferred technique for most surgeons. It is still felt that locally advanced disease is a strong contraindication to MIO, irrespective of approach. There will always be an inherent conversion rate for intraoperative complications, such as uncontrolled haemorrhage, and patient factors, such as adhesions. Where this occurs, morbidity arguably may be higher than with a primary open procedure. There remains no level I evidence on which to draw firmer conclusions and it is unlikely that a multicentre randomised controlled trial will come to fruition. In the eyes of proponents of MIO, this may be irrelevant. When used for carefully selected patients with benign disease or early cancer, data from the literature does show that MIO can result in superior outcome measures and is at least comparable to open resection in this group.

Disclosures Nick Butler, Stuart Collins, Breda Memon, and Muhammed Ashraf Memon have no conflicts of interest or financial ties to disclose.

References

1. Hulscher JB, Tijssen JG, Obertop H, van Lanschot JJ (2001) Transthoracic versus transhiatal resection for carcinoma of the esophagus: a meta-analysis. Ann Thorac Surg 72:306–313
2. Martin DJ, Bessell JR, Chew A, Watson DI (2005) Thoracoscopic and laparoscopic esophagectomy: initial experience and outcomes. Surg Endosc 19:1597–1601
3. Leibman S, Smithers BM, Gotley DC, Martin I, Thomas J (2006) Minimally invasive esophagectomy: short- and long-term outcomes. Surg Endosc 20:428–433
4. Suzuki Y, Urashima M, Ishibashi Y, Abo M, Omura N, Nakada K, Kawasaki N, Eto K, Hanyu N, Yanaga K (2005) Hand-assisted laparoscopic and thoracoscopic surgery (HALTS) in radical esophagectomy with three-field lymphadenectomy for thoracic esophageal cancer. Eur J Surg Oncol 31:1166–1174
5. Palanivelu C, Prakash A, Parthasarathi R, Senthilkumar R, Senthilnathan PR, Rajapandian S (2007) Laparoscopic

esophagogastrectomy without thoracic or cervical access for adenocarcinoma of the gastroesophageal junction: an Indian experience from a tertiary center. Surg Endosc 21:16–20
6. Böttger T, Terzic A, Müller M, Rodehorst A (2007) Minimally invasive transhiatal and transthoracic esophagectomy. Surg Endosc 21:1695–1700
7. Godiris-Petit G, Munoz-Bongrand N, Honigman I, Cattan P, Sarfati E (2006) Minimally invasive esophagectomy for cancer: prospective evaluation of laparoscopic gastric mobilization. World J Surg 30:1434–1440
8. Berrisford RG, Wajed SA, Sanders D, Rucklidge MW (2008) Short-term outcomes following total minimally invasive oesophagectomy. Br J Surg 95:602–610
9. Robertson GS, Lloyd DM, Wicks AC, Veitch PS (1996) No obvious advantages for thoracoscopic two-stage oesophagectomy. Br J Surg 83:675–678
10. Swanstrom LL, Hansen P (1997) Laparoscopic total esophagectomy. Arch Surg 132:943–947
11. Kawahara K, Maekawa T, Okabayashi K, Hideshima T, Shiraishi T, Yoshinaga Y, Shirakusa T (1999) Video-assisted thoracoscopic esophagectomy for esophageal cancer. Surg Endosc 13:218–223
12. Watson DI, Davies N, Jamieson GG (1999) Totally endoscopic Ivor Lewis esophagectomy. Surg Endosc 13:293–297
13. Nguyen NT, Roberts P, Follette DM, Rivers R, Wolfe BM (2003) Thoracoscopic and laparoscopic esophagectomy for benign and malignant disease: lessons learned from 46 consecutive procedures. J Am Coll Surg 197:902–913
14. Luketich JD, Alvelo-Rivera M, Buenaventura PO, Christie NA, McCaughan JS, Litle VR, Schauer PR, Close JM, Fernando HC (2003) Minimally invasive esophagectomy: outcomes in 222 patients. Ann Surg 238:486–494
15. Collins G, Johnson E, Kroshus T, Ganz R, Batts K, Seng J, Nwaneri O, Dunn D (2006) Experience with minimally invasive esophagectomy. Surg Endosc 20:298–301
16. Sutton CD, White SA, Marshall LJ, Berry DP, Veitch PS (2002) Endoscopic-assisted intrathoracic oesophagogastrostomy without thoracotomy for tumours of the lower oesophagus and cardia. Eur J Surg Oncol 28:46–48
17. Wong SK, Chan AC, Lee DW, To EW, Ng EK, Chung SC (2003) Minimal invasive approach of gastric and esophageal mobilization in total pharyngolaryngoesophagectomy: total laparoscopic and hand-assisted laparoscopic technique. Surg Endosc 17: 798–802
18. Costi R, Himpens J, Bruyns J, Cadière GB (2004) Totally laparoscopic transhiatal esophago-gastrectomy without thoracic or cervical access. The least invasive surgery for adenocarcinoma of the cardia? Surg Endosc 18:629–632
19. Espat NJ, Jacobsen G, Horgan S, Donahue P (2005) Minimally invasive treatment of esophageal cancer: laparoscopic staging to robotic esophagectomy. Cancer J 11:10–17
20. Palanivelu C, Prakash A, Senthilkumar R, Senthilnathan P, Parthasarathi R, Rajan PS, Venkatachlam S (2006) Minimally invasive esophagectomy: thoracoscopic mobilization of the esophagus and mediastinal lymphadenectomy in prone position–experience of 130 patients. J Am Coll Surg 203:7–16
21. Avital S, Zundel N, Szomstein S, Rosenthal R (2005) Laparoscopic transhiatal esophagectomy for esophageal cancer. Am J Surg 190:69–74
22. Bann S, Moorthy K, Shaul T, Foley R (2005) Laparoscopic transhiatal surgery of the esophagus. JSLS 9:376–381
23. Tinoco R, El-Kadre L, Tinoco A, Rios R, Sueth D, Pena F (2007) Laparoscopic transhiatal esophagectomy: outcomes. Surg Endosc 21:1284–1287
24. Sanders G, Borie F, Husson E, Blanc PM, Di Mauro G, Claus C, Millat B (2007) Minimally invasive transhiatal esophagectomy: lessons learned. Surg Endosc 21:1190–1193
25. Nguyen NT, Follette DM, Wolfe BM, Schneider PD, Roberts P, Goodnight JE Jr (2000) Comparison of minimally invasive esophagectomy with transthoracic and transhiatal esophagectomy. Arch Surg 135:920–925
26. Bresadola V, Terrosu G, Cojutti A, Benzoni E, Baracchini E, Bresadola F (2006) Laparoscopic versus open gastroplasty in esophagectomy for esophageal cancer: a comparative study. Surg Laparosc Endosc Percutan Tech 16:63–67
27. Braghetto I, Csendes A, Cardemil G, Burdiles P, Korn O, Valladares H (2006) Open transthoracic or transhiatal esophagectomy versus minimally invasive esophagectomy in terms of morbidity, mortality and survival. Surg Endosc 20:1681–1686
28. Smithers BM, Gotley DC, Martin I, Thomas JM (2007) Comparison of the outcomes between open and minimally invasive esophagectomy. Ann Surg 245:232–240
29. Dapri G, Himpens J, Cadière GB (2008) Minimally invasive esophagectomy for cancer: laparoscopic transhiatal procedure or thoracoscopy in prone position followed by laparoscopy? Surg Endosc 22:1060–1069
30. Fabian T, Martin JT, McKelvey AA, Federico JA (2008) Minimally invasive esophagectomy: a teaching hospital's first year experience. Dis Esophagus 21:220–225
31. Fabian T, Martin J, Katigbak M, McKelvey AA, Federico JA (2008) Thoracoscopic esophageal mobilization during minimally invasive esophagectomy: a head-to-head comparison of prone versus decubitus positions. Surg Endosc 22:2485–2491
32. DePaula AL, Hashiba K, Ferreira EAB (1996) Trans-hiatal approach for esophagecotmy. In: Toouli J, Gossot D, Hunter JG (eds) Endosurgery. Churchill Livingstone, New York, pp 293–299
33. Misawa K, Hachisuka T, Kuno Y, Mori T, Shinohara M, Miyauchi M (2005) New procedure for purse-string suture in thoracoscopic esophagectomy with intrathoracic anastomosis. Surg Endosc 19:40–42
34. Thairu N, Biswas S, Abdulaal Y, Ali H (2007) A new method for intrathoracic anastomosis in laparoscopic esophagectomy. Surg Endosc 21:1887–1890
35. Allsop JR (1992) Ligature versus purse string for surgical stapled anastomoses. Aust N Z J Surg 62:740–742
36. Lee KW, Leung KF, Wong KK, Lau KY, Lai KC, Leung SK, Leung LC, Lau KW (1997) One-stage thoracoscopic oesophagectomy: ligature intrathoracic stapled anastomosis. Aust N Z J Surg 67:131–132
37. Luketich JD, Schauer PR, Christie NA, Weigel TL, Raja S, Fernando HC, Keenan RJ, Nguyen NT (2000) Minimally invasive esophagectomy. Ann Thorac Surg 70:906–911
38. Feinstein AR, Sosin DM, Wells CK (1985) The Will Rogers phenomenon: stage migration and new diagnostic techniques as a source of misleading statistics for survival in cancer. N Engl J Med 312:1604–1608