20 Open or Minimally Invasive? Comparison of Early and Late Results

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20.1 Introduction

Esophageal cancer's global incidence continues to increase rapidly. In Western society this is reflected by an increasing incidence of esophageal adenocarcinomas, with the epidemiological shift felt to be related to increased obesity, gastroesophageal reflux disease, and Barrett's esophagus – the dominant risk factors for the development of this tumor. Surgical resection with radical lymphadenectomy, usually after the administration of neoadjuvant chemotherapy or chemoradiotherapy, remains the key component in the multimodality treatment of esophageal cancer. Esophagectomy is a complex surgical procedure for which the mortality rates have historically been significant [1]. In modern practice, in high-volume centers with appropriate multidisciplinary teams, the mortality rate after esophageal resection has been reduced significantly [2]. Despite this, it remains an operation associated with substantial rates of morbidity. During the previous three decades, minimally invasive surgery has been championed as providing a means of reducing postoperative morbidity for a variety of oncological gastrointestinal resections. With regard to esophageal resection, it has been hoped that the application of minimally invasive surgery may similarly reduce postoperative morbidity and mortality. By the early 1990s, some surgeons had developed and used protocols for thoracoscopic esophagectomy, initially restricting its use to T1 and T2 esophageal cancer without neoadjuvant chemoradiation [3, 4]. With time indications for minimally invasive esophageal resection have been expanded to include more advanced disease, irrespective of whether patients have received neoadjuvant treatments.

The techniques which have been described as minimally invasive approaches to esophageal resection vary widely. Many authors have described completely minimally invasive approaches, while others describe hybrid procedures where one stage of the operation is performed either by thoracoscopy or laparoscopy and the other by conventional open surgery. Unlike other minimally invasive procedures, minimally invasive esophagectomy (MIE) has

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not been broadly adopted. No matter what approach is used, MIE remains a very complex operation with many questions remaining unanswered as to the real advantages of applying a minimally invasive technique for resection of a disease which is often advanced at the time of surgery. Mortality, morbidity, oncological radicality, reproducibility of a minimally invasive approach, and the cost of the procedure are some of the topics under debate. Recent reviews [5–7] focusing on the role of MIE have emphasized that the benefits of this approach are controversial. Many comparative nonrandomized and retrospective studies have been conducted between MIE and open esophagectomy, but uncertainty remains about the advantages of any one technique compared to another. In the absence of meta-analyses of randomized controlled studies, this chapter appraises the available literature with regard to the short-term perioperative outcomes and longer-term oncological outcomes for patients undergoing minimally invasive resection for esophageal cancer.

20.2 MIE Techniques

As there has never been a consensus regarding the superiority of any of the various open esophagectomy techniques, it is unsurprising that there is no agreement on what constitutes the best minimally invasive approach.

Completely minimally invasive approaches to esophageal resection attempt to replicate established open procedures. A minimally invasive transhiatal technique utilizes laparoscopic abdominal dissection and preparation of the gastric conduit followed by a cervical anastomosis created via a traditional open approach in the neck. Mediastinal dissection of periesophageal lymph nodes, including those in the subcarinal station, can be assessed through the hiatus using the lighting and magnification afforded by the laparoscopic camera. The esophageal specimen can be removed through the neck incision. Some surgeons prefer to combine the laparoscopic transhiatal approach with a minilaparotomy to facilitate gastric tube creation as well as to remove the specimen. Finally, the esophagus can also be removed from the mediastinum via an inversion technique with or without division of the vagus nerve. As with open surgery, many surgeons prefer a thoracoscopic approach, typically performed through the right chest, with patients positioned in lateral decubitus or prone positions [8, 9]. Thoracoscopy can be used as a part of a three-stage MIE, where the procedure begins in the chest and ends with laparoscopy and a cervical anastomosis, or as part of the two-stage Ivor-Lewis esophagectomy where the esophagogastric anastomosis resides in the chest. In this procedure the specimen is removed through a mini-thoracotomy, and the anastomosis is created at the apex of the chest.

Combinations of open and minimally invasive techniques (hybrid techniques) are perhaps more widely utilized, such as laparoscopy with thoracotomy or thoracoscopy with laparotomy. These hybrid techniques are applied for a variety of reasons and may be necessitated by oncological considerations, prior surgery in either cavity, surgeon experience, and surgeon preference.

Although the goal of MIE is to perform an equivalent operation to the open procedure without omitting any critical steps, some aspects considered as routine for open esophagectomy have fallen out of favor with many surgeons, such as performance of a pyloroplasty and jejunostomy placement.

20.3 Early Results (Tables 20.1 and 20.2)

The primary goal of MIE is to decrease surgical morbidity associated with the open approach. In the setting of a randomized controlled trial, only a single direct comparison of open and minimally invasive approaches has been published [31] with the final results of the French MIRO (oesophagectoMIe pour cancer paR voie conventionnelle ou coeliO-assistée) trial awaited [32]. At present, the majority of data derives from retrospective nonrandomized series and suggests that mortality rates appear equivalent with some suggestion of benefit in terms of overall morbidity favoring a

Table 20.1 Mortality and overall morbidity of minimally invasive and open esophagectomy

Authors (year)	*n*	Approaches	Mortality *n* (%)	Overall morbidity *n* (%)
Law et al. (1997) [10]	22	MIE (TSO)	0	18 (81.8)
	63	Open	0	63 (100)
Nguyen et al. (2000) [11]	18	MIE (TLSO)	0	7 (38.9)
	36	Open	0	19 (52.8)
Osugi et al. (2003) [12]	77	MIE (VATS)	0	31 (40.3)
	72	Open	0	32 (44.4)
Kunisaki et al. (2004) [13]	15	MIE (VATS + HALS)	0	NS
	30	Open	0	NS
Van den Broek et al. (2004) [14]	25	MIE (THO)	0	14 (70)
	20	Open	0	18 (72)
Bresadola et al. (2006) [15]	14	MIE (THO and TLSO)	0	8 (57.1)
	14	Open	0	6 (42.9)
Bernabe et al. (2005) [16]	17	MIE (THO)	0	NS
	14	Open	0	NS
Shiraishi et al. (2006) [17]	116	MIE (TLSO)	3 (2.6)	NS
	37	Open	3 (8.1)	NS
Braghetto et al. (2006) [18]	47	MIE (VATS/LSO)	3 (6.3)	18 (38.2)
	119	Open	13 (10.9)	72 (60.5)
Smithers et al. (2007) [19]	332	MIE (TLSO)	7 (2.1)	207 (62.3)
	114	Open	3 (2.6)	76 (66.7)
Fabian et al. (2008) [9]	22	MIE (TLSE)	1 (4.5)	15 (68.2)
	43	Open	4 (9.8)	31 (72.1)
Zingg et al. (2009) [20]	56	MIE (TLSO)	2 (3.6)	19 (34.5)
	98	Open	6 (6.1)	20 (23.5)
Perry et al. (2009) [21]	21	MIE (LIO)	0	13 (62)
	21	Open	1 (5)	17 (81)
Parameswaran et al. (2009) [22]	50	MIE (TLSO)	1 (2)	24 (48)
	30	Open	1 (3)	15 (50)
Pham et al. (2010) [23]	44	MIE (TLSO)	3 (6.8)	NS
	46	Open	2 (4.3)	NS
Schoppman et al. (2010) [24]	31	MIE (TLSO)	0	11 (35.5)
	31	Open	0	23 (74.2)
Singh et al. (2010) [25]	33	MIE (TLSO)	Values NS	Values NS
	31	Open	$p = 0.34$	$P = 0.06$
Mamidanna et al. (2012) [26]	1155	MIE (TLSO,HMIO)	46 (4.0)	NS
	6347	Open	274 (4.3)	NS
Ben-David et al. (2012) [27]	100	MIE (TLSO)	1 (1)	NS
	32	Open	2 (5)	NS
Briez et al. (2012) [28]	140	MIE (HMIO)	2.1	35.7
	140	Open	12.9	59.3
Xie et al. (2014) [29]	106	MIE (TLSO)	2 (1.9)	28 (26.4)
	163	Open	4 (2.5)	56 (34.4)
Hsu et al. (2014) [30]	66	MIE (TLSO)	5 (7.6)	NS
	63	Open	5 (7.9)	NS

MIE minimally invasive esophagectomy, *VATS* video-assisted thoracoscopic surgery esophagectomy, *HMIO* hybrid MIO, *HALS* hand-assisted laparoscopic oesophagectomy, *TSE* thoracoscopic-assisted esophagectomy, *TLSE* thoraco-laparoscopic surgery esophagectomy, *LIE* laparoscopic inversion esophagectomy, *LSE* laparoscopic esophagectomy, *NS* not stated

Table 20.2 Comparison of rates of morbidities for MIE and open esophagectomy

Authors (year)	*n*	Approaches	Pneumonia *n* (%)	Cardiac arrhythmia *n* (%)	Anastomotic leak *n* (%)	Gastric conduit ischemia n (%)	Chylothorax *n* (%)	Length of stay (days)	Operative blood loss (mls)	Operative time (minutes)
Law et al. (1997) [10]	22	MIE (TSO)	3 (13.6)	3 (13.6)	0	NS	NS	NS	450 (200–800)	240 (160–350)
	63	Open	11 (17.5)	14 (22.2)	2 (3.2)	NS	NS	NS	700 (300–2500)	250 (190–420)
Nguyen et al. (2000) [11]	18	MIE (TLSO)	2 (11.1)	NS	2 (11.1)	0	0	11.3 ± 14.2	297 ± 233	364 ± 73
	36	Open	6 (16.7)	NS	4 (11.1)	1 (2.8)	1 (2.8)	22.8 ± 18.0	1108 ± 790	411 ± 93
Osugi et al. (2003) [12]	77	MIE (VATS)	12 (15.6)	1 (1.3)	1 (1.3)	0	3 (3.9)	NS	284 (330)	227 (90)
	72	Open	14 (19.4)	3 (4.2)	2 (2.8)	0	0	NS	310 (170)	186 (35)
Kunisaki et al. (2004) [13]	15	MIE (VATS + HALS)	0	NS	2 (13.3)	NS	NS	29.6 ± 12.9	447.9 (±214.8)	544.4 (±64.5)
	30	Open	1 (3.3)	NS	1 (3.3)	NS	NS	32.7 ± 14.0	674.7 (±445.6)	487.8 (±97.8)
Van den Broek et al. (2004) [14]	25	MIE (THO)	2 (8)	NS	2 (8)	0	2 (8)	16	NS	NS
	20	Open	2 (10)	NS	3 (15)	0	0	16	NS	NS
Bresadola et al. (2006) [15]	14	MIE (THO and TLSO)	1 (7.1)	NS	1 (7.1)	NS	0	16.4 (±8.4)	NS	469.0 (±42.6)
	14	Open	2 (14.2)	NS	2 (14.2)	NS	0	22.3 (±10.6)	NS	370.8 (±16.7)
Bernabe et al. (2005) [16]	17	MIE (THO)	NS	NS	NS	NS	NS	9.1 (±3.2)	331 (±220)	336 (±53)
	14	Open	NS	NS	NS	NS	NS	11.6 (±2.9)	542 (±212)	388 (±102)
Shiraishi et al. (2006) [17]	116	MIE (TLSO)	25 (21.6)	3 (2.6)	13 (11.2)	NS	NS	NS	670.2 (±561.1)	426.0 (±87.1)
	37	Open	12 (32.4)	4 (10.8)	9 (24.3)	NS	NS	NS	487.4 (±110.5)	487.4 (±110.5)
Braghetto et al. (2006) [18]	47	MIE (VATS/LSO)	7 (14.8)	NS	3 (6.4)	0	1 (2.1)	NS	NS	NS
	119	Open	22 (18.5)	NS	17 (14.3)	1 (0.8)	0	NS	NS	NS

Smithers et al. (2007) [19]	332	MIE (TLSO)	87 (26.2)	55 (16.6)	18 (5.4)	5 (1.5)	17 (5.1)	11 (7–49)	300 (15–1000)	330 (270–540)
	114	Open	35 (27.8)	21 (18.4)	10 (8.7)	2 (1.7)	7 (6.1)	14 (8–44)	600 (0–3000)	300 (150–480)
Fabian et al. (2008) [9]	22	MIE (TLSE)	1 (4.5)	4 (18.2)	3 (13.6)	1 (4.5)	0	9.5	178 (±96)	333 (±72)
	43	Open	10 (23.3)	8 (18.6)	3 (7.0)	0	2 (4.7)	11	356 (±136)	270 (±87)
Zingg et al. (2009) [20]	56	MIE (TLSO)	17 (30.9)	NS	NS	NS	NS	19.7 (±2.0)	320 (±49)	250 (±7.2)
	98	Open	33 (38.8)	NS	NS	NS	NS	21.9 (±2.0)	857 (±82)	209 (±7.8)
Perry et al. (2009) [21]	21	MIE (LIO)	1 (5)	4 (19)	4 (19)	NS	NS	10 (8–14)	168 (149)	399 (86)
	21	Open	2 (10)	7 (33)	6 (29)	NS	NS	14 (10–19)	526 (289)	408 (127)
Parameswaran et al. (2009) [22]	50	MIE (TLSO)	4 (8)	NS	4 (8)	5 (16)	3 (6)	12 (8–86)	NS	442 (305–580)
	30	Open	2 (7)	NS	1 (3)	2 (10)	1 (3)	10 (6–56)	NS	266 (219–390)
Pham et al. (2010) [23]	44	MIE (TLSO)	11 (25)	NS	4 (9)	1 (2)	NS	15 (12–20)	407 (±267)	543 (72.6)
	46	Open	7 (15)	NS	5 (11)	1 (2)	NS	14 (11–23)	780 (±610)	437 (97.0)
Schoppman et al. (2010) [24]	31	MIE (TLSO)	2 (6.2)	NS	1 (3.2)	0	2 (6.4)	NS	NS	411 (270–600)
	31	Open	11 (35.5)	NS	8 (25.8)	1 (3.2)	1 (3.2)	NS	NS	400 (240–550)
Singh et al. (2010) [25]	33	MIE (TLSO)	NS	NS	NS	NS	NS	No difference ($p=0.17$)	Reduced after MIE ($p<.01$)	Longer for MIE ($p<0.01$)
	31	Open	NS	NS	NS	NS	NS			
Mamidanna et al. (2012) [26]	1155	MIE (TLSO, HMIO)	230 (19.9)	102 (8.8)	NS	NS	NS	15 (12–23)	NS	NS
	6347	Open	1181 (18.6)	611 (9.6)	NS	NS	NS	15 (12–22)	NS	NS
Ben-David et al. (2012) [27]	100	MIE (TLSO)	9 (9)	8 (8)	5 (5)	NS	3 (3)	7.5 (6–49)	125 (100–300)	330 (270–480)
	32	Open	5 (15.6)	NS	4 (12.5)	NS	NS	14 (10–98)	NS	NS

(continued)

Table 20.2 (continued)

Authors (year)	*n*	Approaches	Pneumonia *n* (%)	Cardiac arrhythmia *n* (%)	Anastomotic leak *n* (%)	Gastric conduit ischemia n (%)	Chylothorax *n* (%)	Length of stay (days)	Operative blood loss (mls)	Operative time (minutes)
Briez et al. (2012) [28]	140	MIE (HMIO)	15.7	NS	5.7	0.7	NS	12 (8–80)	NS	NS
	140	Open	42.9	NS	4.3	0.0	NS	16 (8–180)	NS	NS
Xie et al. (2014) [29]	106	MIE (TLSO)	2 (1.9)	NS	5 (4.7)	NS	4 (3.8)	11.8 (±6.7)	187.2 (±37.8)	249.6 (±41.7)
	163	Open	8 (4.9)	NS	6 (3.7)	NS	5 (3.1)	13.9 (±7.3)	198.5 (±46.5)	256.3 (±41.7)
Hsu et al. (2014) [30]	66	MIE (TLSO)	7 (10.6)	NS	18 (27.3)	NS	4 (6.1)	NS	462.4 (±467.8)	510.9 (±121.3)
	63	Open	16 (25.4)	NS	19 (30.2)	NS	3 (4.8)	NS	615.5 (±591.6)	460.5 (±92.4)

MIE minimally invasive esophagectomy, *VATS* video-assisted thoracoscopic surgery esophagectomy, *HMIO* hybrid MIE, *HALS* hand-assisted laparoscopic oesophagectomy, *TSE* thoracoscopic-assisted esophagectomy, *TLSE* thoracolaparoscopic surgery esophagectomy, *LIE* laparoscopic inversion esophagectomy, *LSE* laparoscopic esophagectomy, *NS* not stated minimally invasive approach (Tables 20.1 and 20.2). It is likely that the benefits of MIE may be overshadowed by the persistent rate of significant morbidity which continues to occur independent of surgical approach. It seems conceivable that, in the absence of such complications, patients with a minimal access approach enjoy quicker recovery, quicker return to normal activities, and decreased long-term pain when compared to patients with similarly uncomplicated open procedures. This, however, has yet to be proven.

Results coming from three published meta-analyses, based on nonrandomized comparative data, are contradictory. Two did not find significant differences between the MIE and the open approaches [33, 34]. The third suggests that patients undergoing MIE had better operative and postoperative outcomes with no compromise in oncological outcomes (as assessed by lymph node retrieval) [7]. Patients undergoing MIE had significantly lower blood loss and shorter postoperative ICU and hospital stay. There was a 50 % decrease in total morbidity in the MIE group. Subgroup analysis of comorbidities demonstrated significantly lower incidence of respiratory complications after MIE; however, other postoperative outcomes such as anastomotic leak, anastomotic stricture, gastric conduit ischemia, chyle leak, vocal cord palsy, and 30-day mortality were comparable between the two techniques. The benefit of at least one endoscopic stage in hybrid techniques (thoracoscopy with laparotomy or laparoscopy with thoracotomy) was noted. Even with only one phase being minimally invasive, blood loss and respiratory complications were still found to be lower, consistent with open versus totally MIE analysis, and highlight the purported advantages of applying a minimally invasive approach to esophagectomy.

20.4 Long-Term Results (Table 20.3)

If MIE is to become the approach of choice, then it must be demonstrated not to compromise oncological outcomes. Improved lighting and visibility, along with the magnification afforded by minimally invasive equipment, may prove superior for meticulous dissection and lymph node harvest. However, until large series report long-term survival by stage or results of large randomized trials are published, the true oncologic value of MIE will remain controversial. Table 20.3 reflects the fact that no study to date has shown conclusive evidence of improved overall survival favoring a minimally invasive resection. While several studies have suggested a benefit in terms of lymph node harvest, many have failed to meet the broadly accepted recommendations of the number of lymph nodes which should be retrieved for optimum staging and prognosis (Table 20.3). This puts into some question the quality of resection in several studies and makes oncological comparisons difficult. More data is simply required in this regard from future randomized controlled trials.

20.5 Randomized Controlled Trials

To date, only one multicenter randomized controlled trial (TIME) has been published comparing the results of minimally invasive and open esophagectomy [31]. This trial randomly assigned 56 patients to open esophagectomy and 59 to a minimally invasive operation with all patients receiving equivalent neoadjuvant chemotherapy or chemoradiotherapy regimes. Both minimally invasive and open surgical groups had a mixture of two-stage and three-stage operations with the majority of patients having a cervical anastomosis. The primary outcome measure chosen was pulmonary infection within 2 weeks of surgery defined by clinical manifestation of pneumonia confirmed by radiological imaging and a positive sputum sample. Sixteen (29 %) patients in the open surgical group and 5 (9 %) patients in the minimally invasive group ($p=0.005$) developed pneumonia in the first two postoperative weeks. Prima facie this appears to suggest a significant benefit in terms of respiratory complications in favor of the minimally invasive approach. Several observations and qualifications do however need

Table 20.3 Long-term oncological outcomes for MIE and open esophagectomy

Authors (year)	*N*	Approaches	Number of lymph nodes retrieved (median)	RO resection rate n (%)	3-year survival
Law et al. (1997) [10]	22	MIE (TSO)	7 [2–13]	10	62 % (2 years)
	63	Open	13 [5–34]	NS	63 % (2 years)
Nguyen et al. (2000) [11]	18	MIE (TLSO)	10.8 ± 8.4	18	NS
	36	Open	6.6 ± 5.8	NS	NS
Osugi et al. (2003) [12]	77	MIE (VATS)	33.9 ± 12	NS	70 %
	72	Open	32.8 ± 14	NS	60 %
Kunisaki et al. (2004) [13]	15	MIE (VATS + HALS)	24.5 ± 10	NS	NS
	30	Open	26.6 ± 10.4	NS	NS
Van den Broek et al. (2004) [14]	25	MIE (THO)	7 ± 4.9	21 (84)	60 % (f/u 17 ± 11 months)
	20	Open	6.5 ± 4.9	18 (90)	50 % (f/u 54 ± 16 months)
Bresadola et al. (2005) [15]	14	MIE (THO/TLSO)	22.2 ± 12	NS	NS
	14	Open	18.6 ± 13.4	NS	NS
Bernabe et al. (2005) [16]	17	MIE (THO)	9.8 (NS)	NS	NS
	14	Open	8.7 (NS)	NS	NS
Shiraishi et al. (2006) [17]	116	MIE (TLSO)	31.8 (NS)	NS	NS
	37	Open	30.1 (NS)	NS	NS
Braghetto et al. (2006) [18]	47	MIE (VATS/LSO)	NS	NS	45.5 %
	119	Open	NS	NS	32.5 %
Smithers et al. (2007) [19]	332	MIE (TLSO)	17 [9–33]	263	42 %
	114	Open	16 [1–44]	90	30 %
Fabian et al. (2008) [9]	22	MIE (TLSE)	15 ± 6	22 (100)	NS
	43	Open	8 ± 7	NS	NS
Zingg et al. (2009) [20]	56	MIE (TLSO)	5.7 ± 0.4	NS	Median survival – 35 months MIE, 29 months open
	98	Open	6.7 ± 0.5	NS	
Perry et al. (2009) [21]	21	MIE (LIO)	10 [4–12]	NS	NS
	21	Open	3 [0–7]	NS	NS
Parameswaran et al. (2009) [22]	50	MIE (TLSO)	23 [7–49]	NS	74 % (2-year survival)
	30	Open	10 [2–23]	NS	58 % (2-year survival)
Pham et al. (2010) [23]	44	MIE (TLSO)	13 [9–15]	NS	NS
	46	Open	8 [3–14]	NS	NS
Schoppman et al. (2010) [24]	31	MIE (TLSO)	17.9 ± 7.7	29 (93.5)	64 %
	31	Open	20.5 ± 12.6	30 (96.8)	46 %
Singh et al. (2010) [25]	33	MIE (TLSO)	14 (6–16)	30	55 % (2-year survival)
	31	Open	8 (3–14)	30	32 % (2-year survival)
Mamidanna et al. (2012) [26]	1155	MIE (TLSO/HMIO)	NS	NS	NS
	6347	Open	NS	NS	NS
Ben-David et al. (2012) [27]	100	MIE (TLSO)	NS	99 (99)	NS
	32	Open	NS	32 (100)	NS

Table 20.3 (continued)

Authors (year)	*N*	Approaches	Number of lymph nodes retrieved (median)	RO resection rate n (%)	3-year survival
Briez et al. (2012) [28]	140	MIE (HMIO)	22 [8–53]	85.7	58 % (2-year survival)
	140	Open	22 [6–56]	87.9	57 % (2-year survival)
Xie et al. (2014) [29]	106	MIE (TLSO)	30.4 (±5.4)	NS	NS
	163	Open	30.2 (±5.0)	NS	NS
Hsu et al. (2014) [30]	66	MIE (TLSO)	28.3 (±16.6)	64 (97.0)	70.9 %
	63	Open	25.9 (±15.3)	61 (96.8)	47.6 %

MIE minimally invasive esophagectomy, *VATS* video-assisted thoracoscopic surgery esophagectomy, *HMIO* hybrid MIO, *HALS* hand-assisted laparoscopic oesophagectomy; *TSE* thoracoscopic-assisted esophagectomy, *TLSE* thoraco-laparoscopic surgery esophagectomy, *LIE* laparoscopic inversion esophagectomy, *LSE* laparoscopic esophagectomy, *NS* not stated

to be made. Intraoperative single-lung ventilation was practiced only for the open surgical group, and the open group had a very high level of recurrent laryngeal nerve palsy (14 %) compared to the minimally invasive group (2 %). Both of these factors clearly put the patients having an open operation at higher risk of postoperative respiratory complications. Further many non-studied variables – malnutrition, previous and current smoking, pulmonary comorbidities, functional status, and clinical TNM (tumor, node, metastases) stage – have all been shown to strongly influence the primary end point of this trial. More data is therefore required.

There are two other multicenter randomized controlled trials of interest. The French multicenter phase III MIRO trial [32] has randomized patients to either hybrid esophagectomy (laparoscopic gastric mobilization and open right thoracotomy) or open esophagectomy. The MIRO trial tests the impact of laparoscopic gastric conduit creation with open thoracotomy (hybrid procedure) on major 30-day postoperative morbidity, especially on pulmonary complications. It hypothesizes that hybrid MIE may decrease major postoperative morbidity without compromising oncological outcomes through an easily reproducible surgical procedure. Secondary objectives are to assess the overall 30-day morbidity, 30-day mortality, disease-free and overall survival, quality of life, and medico-economic analysis. The short-term results have been recently presented [35]. The trial randomly assigned 104 patients to open esophagectomy and 103 to a hybrid approach group. Sixty-seven (64.4 %) patients in the open group had major postoperative morbidity compared to 37 (35.9 %) in the hybrid group (OR 0·31, 95 % CI 0·18-0·55; $p=0\cdot0001$). Thirty-one (30.1 %) patients after an open operation had major pulmonary complications compared to 18 (17.7 %) after a hybrid approach ($p=0\cdot037$), whereas 30-day mortality was 5 (4.9 %) versus 5 (4.9 %), respectively. The MIRO results provide further evidence that a minimally invasive approach may reduce the short-term insult of esophagectomy. The longer-term oncological results are awaited with interest. In the United Kingdom, patients are currently being recruited into a phase II trial [36] comparing a totally minimally invasive operation, hybrid approach (laparoscopic gastric mobilization and open chest) and open esophagectomy. Results for phase II of this study are not yet accumulated and recruitment to the planned phase III trial not yet commenced.

Conclusions

MIE has been gaining in popularity, but, as with open surgery, no consensus has been reached regarding the superiority of any particular MIE adaptation. Even if some large comparative studies suggest a significantly better postoperative course following MIE, without compromise of oncological outcomes, more data is needed from randomized trials. Randomized trials are, however, difficult due to the wide variety of techniques available, the heterogeneity in surgeons' preferences, the relative low number of procedures performed, the complexity of such surgery, and the variety and definition of postoperative complications after esophagectomy. Certainly the positive results of the TIME trial and the soon to be published MIRO trial add credence to what many surgeons find intuitive – that a less invasive approach can reduce morbidity after esophagectomy. Rates of postoperative mortality have fallen in specialist centers; focus must turn to minimizing the traditionally high level of morbidity associated with this operation.

To date, data coming from nonrandomized studies do suggest MIE is safe and at least comparable to open resection for both surgical and oncological outcomes. Data from meta-analyses suggest that MIE may have advantages in terms of less blood loss, less time in intensive care, fewer pulmonary complications, and shorter hospital stay. However, the effect of MIE on quality of life and return to normal activity has not been assessed nor have medico-economic analyses been performed. More large randomized controlled trials are required. Results from the MIRO trial will soon be published and will offer a higher level of evidence for this highly debated procedure.

Conflicts of Interest The authors declare that they have no competing interests.

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References

1. Birkmeyer JD, Siewers AE, Finlayson EV et al (2002) Hospital volume and surgical mortality in the United States. N Engl J Med 346:1128–1137
2. Low DE, Kunz S, Schembre D et al (2007) Esophagectomy–it's not just about mortality anymore: standardized perioperative clinical pathways improve outcomes in patients with esophageal cancer. J Gastrointest Surg 11:1395–1402
3. Akaishi T, Kaneda I, Higuchi N et al (1996) Thoracoscopic en bloc total esophagectomy with radical mediastinal lymphadenectomy. J Thorac Cardiovasc Surg 112:1533–1540
4. Gossot D, Fourquier P, Celerier M (1993) Thoracoscopic esophagectomy: technique and initial results. Ann Thorac Surg 56:667–670
5. Gemmill EH, McCulloch P (2007) Systematic review of minimally invasive resection for gastro-oesophageal cancer. Br J Surg 94:1461–1467
6. Mariette C, Robb WB (2012) Open or minimally invasive resection for oesophageal cancer? Recent Results Cancer Res 196:155–167
7. Nagpal K, Ahmed K, Vats A et al (2010) Is minimally invasive surgery beneficial in the management of esophageal cancer? A meta-analysis. Surg Endosc 24:1621–1629
8. Dapri G, Himpens J, Cadiere GB (2008) Minimally invasive esophagectomy for cancer: laparoscopic transhiatal procedure or thoracoscopy in prone position followed by laparoscopy? Surg Endosc 22:1060–1069
9. Fabian T, Martin JT, McKelvey AA et al (2008) Minimally invasive esophagectomy: a teaching hospital's first year experience. Dis Esophagus 21: 220–225
10. Law S, Fok M, Chu KM et al (1997) Thoracoscopic esophagectomy for esophageal cancer. Surgery 122:8–14
11. Nguyen NT, Follette DM, Wolfe BM et al (2000) Comparison of minimally invasive esophagectomy with transthoracic and transhiatal esophagectomy. Arch Surg 135:920–925
12. Osugi H, Takemura M, Higashino M et al (2003) A comparison of video-assisted thoracoscopic oesophagectomy and radical lymph node dissection for squamous cell cancer of the oesophagus with open operation. Br J Surg 90:108–113
13. Kunisaki C, Hatori S, Imada T et al (2004) Video-assisted thoracoscopic esophagectomy with a voice-controlled robot: the AESOP system. Surg Laparosc Endosc Percutan Tech 14:323–327
14. Van den Broek WT, Makay O, Berends FJ et al (2004) Laparoscopically assisted transhiatal resection for malignancies of the distal esophagus. Surg Endosc 18:812–817
15. Bresadola V, Terrosu G, Cojutti A et al (2006) Laparoscopic versus open gastroplasty in esophagectomy for esophageal cancer: a comparative study. Surg Laparosc Endosc Percutan Tech 16:63–67
16. Bernabe KQ, Bolton JS, Richardson WS (2005) Laparoscopic hand-assisted versus open transhiatal esophagectomy: a case-control study. Surg Endosc 19:334–337

17. Shiraishi T, Kawahara K, Shirakusa T et al (2006) Risk analysis in resection of thoracic esophageal cancer in the era of endoscopic surgery. Ann Thorac Surg 81:1083–1089
18. Braghetto I, Csendes A, Cardemil G et al (2006) Open transthoracic or transhiatal esophagectomy versus minimally invasive esophagectomy in terms of morbidity, mortality and survival. Surg Endosc 20:1681–1686
19. Smithers BM, Gotley DC, Martin I et al (2007) Comparison of the outcomes between open and minimally invasive esophagectomy. Ann Surg 245:232–240
20. Zingg U, McQuinn A, DiValentino D et al (2009) Minimally invasive versus open esophagectomy for patients with esophageal cancer. Ann Thorac Surg 87:911–919
21. Perry KA, Enestvedt CK, Pham T et al (2009) Comparison of laparoscopic inversion esophagectomy and open transhiatal esophagectomy for high-grade dysplasia and stage I esophageal adenocarcinoma. Arch Surg 144:679–684
22. Parameswaran R, Veeramootoo D, Krishnadas R et al (2009) Comparative experience of open and minimally invasive esophagogastric resection. World J Surg 33:1868–1875
23. Pham TH, Perry KA, Dolan JP et al (2010) Comparison of perioperative outcomes after combined thoracoscopic-laparoscopic esophagectomy and open Ivor-Lewis esophagectomy. Am J Surg 199:594–598
24. Schoppmann SF, Prager G, Langer FB et al (2010) Open versus minimally invasive esophagectomy: a single-center case controlled study. Surg Endosc 24:3044–3053
25. Singh RK, Pham TH, Diggs BS et al (2010) Minimally invasive esophagectomy provides equivalent oncologic outcomes to open esophagectomy for locally advanced (stage II or III) esophageal carcinoma. Arch Surg 146:711–714
26. Mamidanna R, Bottle A, Aylin P et al (2012) Short-term outcomes following open versus minimally invasive esophagectomy for cancer in England: a population-based national study. Ann Surg 255:197–203
27. Ben-David K, Sarosi GA, Cendan JC et al (2012) Decreasing morbidity and mortality in 100 consecutive minimally invasive esophagectomies. Surg Endosc 26:162–167
28. Briez N, Piessen G, Torres F et al (2012) Effects of hybrid minimally invasive oesophagectomy on major postoperative pulmonary complications. Br J Surg 99:1547–1553
29. Xie MR, Liu CQ, Guo MF et al (2014) Short-term outcomes of minimally invasive Ivor-Lewis esophagectomy for esophageal cancer. Ann Thorac Surg 97:1721–1727
30. Hsu PK, Huang CS, Wu YC et al (2014) Open versus thoracoscopic esophagectomy in patients with esophageal squamous cell carcinoma. World J Surg 38:402–409
31. Biere SS, van Berge Henegouwen MI, Maas KW et al (2012) Minimally invasive versus open oesophagectomy for patients with oesophageal cancer: a multicentre, open-label, randomised controlled trial. Lancet 379:1887–1892
32. Briez N, Piessen G, Bonnetain F et al (2011) Open versus laparoscopically-assisted oesophagectomy for cancer: a multicentre randomised controlled phase III trial – the MIRO trial. BMC Cancer 11:310
33. Biere SS, Cuesta MA, van der Peet DL (2009) Minimally invasive versus open esophagectomy for cancer: a systematic review and meta-analysis. Minerva Chir 64:121–133
34. Sgourakis G, Gockel I, Radtke A et al (2010) Minimally invasive versus open esophagectomy: meta-analysis of outcomes. Dig Dis Sci 55:3031–3040
35. Mariette C, Meunier B, Pezet D et al (2014) Hybrid minimally invasive versus open oesophagectomy for patients with oesophageal cancer: a multicentre, open-label, randomised phase III controlled trial, the MIRO trial. Paper presented at the American society of clinical oncology gastrointestinal cancers symposium, San Francisco, 15–17 Jan 2015
36. Avery KN, Metcalfe C, Berrisford R et al (2014) The feasibility of a randomized controlled trial of esophagectomy for esophageal cancer–the ROMIO (Randomized Oesophagectomy: Minimally Invasive or Open) study: protocol for a randomized controlled trial. Trials 15:200