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REVIEW ARTICLE

Minimally invasive esophagectomy performed with the patient in a prone position: a systematic review

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Abstract
Purpose We reviewed the surgical results of minimally invasive esophagectomy for esophageal cancer, performed with the patient in a prone position (MIE-PP), to assess its benefits.
Methods A systematic literature search was performed, and articles that fully described the surgical results of MIE-PP were selected. Parameters such as operative time, blood loss, and postoperative outcomes were compared with those obtained for open transthoracic esophagectomy (OE) and minimally invasive esophagectomy in a lateral decubitus position (MIE-LP).
Results The conversion rate from MIE-PP to open surgery was very low. MIE-PP was associated with longer operative time and lower blood loss than OE. Although studies from a single institution did not show an apparent difference in morbidity or mortality among the three operative groups, results of a multicenter randomized controlled trial showed a reduction in pulmonary infection and recurrent laryngeal nerve palsy in MIE-PP, compared with OE. The benefits of MIE-PP vs. those of MIE-LP remain controversial.
Conclusion Theoretically, the operative results of MIE-PP might be better than those of MIE-LP for patients with esophageal cancer; however, studies have not yet verified this. Further clinical studies are required to establish whether the advantages of MIE-PP can be translated into clinical outcome.

Keywords Minimally invasive · Esophageal cancer · Prone position

Introduction

The incidence of esophageal cancer has increased over the past two decades [1, 2]. Esophagectomy is the mainstay of curative modalities for localized esophageal cancer [3–6], but it is a complex and highly invasive operation, associated with significant operative morbidity and mortality [7–9]. The long thoracotomy incision and one-lung ventilation during esophagectomy are thought to be partly responsible for the high surgical invasiveness of this procedure and its subsequent respiratory complications. In an effort to reduce these issues, a transhiatal esophagectomy was developed to decrease the damage to the chest wall and the incidence of postoperative pulmonary complications [10]. However, a blind procedure carries a risk of injury to the vessels, nerves, and respiratory organs, and also has some limitations in relation to lymph node dissection and survival benefit [11, 12].

Over the last two decades, thoracoscopic surgery has attracted much attention as a less invasive approach for the treatment for benign and malignant diseases [13–15]. In 1992, Cuschieri et al. [16] first reported performing thoracoscopic minimally invasive esophagectomy (MIE) for esophageal cancer, which sparked the interest of many surgeons because MIE has the potential to lower the morbidity associated with resection and to enable a quicker return to normal function. By the late 1990s, several surgeons had performed MIE and demonstrated its safety and feasibility

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[17–21]. After these exploratory investigations, reports from large-volume centers began to reveal improvements in the surgical results associated with MIE [22–26]. Thus, the number of MIE procedures being performed is increasing. Large single-institution studies have demonstrated that the results of MIE may be comparable to those for open transthoracic esophagectomy (OE) [27–32]. Two meta-analyses comparing MIE with OE have shown that MIE is associated with lower operative blood loss, shorter intensive care unit and hospital stays, and fewer postoperative respiratory complications [33, 34]. Because of the diversity of operative techniques used for MIE and surgeons' experience, multi-institutional randomized studies were not performed until recently. Standardization of the surgical technique has allowed further investigation of MIE, and two multi-institutional randomized control studies have been performed [35, 36]. These studies demonstrated fewer complications and a shorter hospital stay after MIE than after OE.

Until recently, MIE was performed exclusively with the patient in the left lateral decubitus position (MIE-LP). However, MIE-LP involves the total collapse and retraction of the lung, and requires a special team consisting of an expert surgeon, an expert assistant, and an expert endoscopist. In 2006, Palanivelu et al. [37] reported on a large number of MIE procedures that were performed while the patient was in a prone position (MIE-PP). Their single-institutional study demonstrated that MIE-PP was feasible, had a low incidence of respiratory complications, and could be performed within a shorter operative time because of the excellent exposure of the operative field and the better ergonomics of the surgeon's stance. Since that report, MIE-PP has become a popular approach for patients with esophageal cancer [38].

MIE has advanced dramatically, with several reports documenting improvements in the procedure and clinical results. However, these reports describe a variety of techniques and the oncological adequacy of the resection seems to vary widely. The apparent benefits of MIE for patients with esophageal cancer have not yet been confirmed [39–41], and now two standard procedures, MIE-LP and MIE-PP, are being performed by different surgeons at different institutions. A number of issues concerning the efficacy and oncological outcomes of MIE-PP, compared with MIE-LP, need to be addressed before a multi-center trial can be performed. To clarify these issues, we systematically reviewed the currently available literature and assessed the surgical benefits of MIE-PP for patients with esophageal cancer.

Methods

A systematic literature search of PubMed and Embase databases was performed, entering "esophagectomy", "thoracoscopic", and "minimally invasive" as key words and a publication date range of between 2006 and 2013. The search was expanded to include the reference articles mentioned in each report. Then, we selected further articles related to MIE-PP, in which surgical results such as the operative time and blood loss, and short-term surgical outcomes were described [36, 37, 42–54]. When we found overlapping results related to the same patients but published in different reports, only the most recent article was selected. Among the articles that were selected, five compared their results to those for OE and five compared them to those for MIE-LP. We compared the results of MIE-PP with those for OE and MIE-LP, to confirm whether MIE-PP afforded any benefit to patients in terms of safety and surgical results or oncological adequacy.

Indications and techniques for MIE-PP

Patient selection

The indications for MIE-PP are similar to those for MIE-LP. Initially, MIE was used to resect treatment-naïve early stage esophageal cancer and was shown to be both safe and feasible [27, 55]. The indications for MIE then expanded to include advanced stage cancer and cancers that had been treated with neoadjuvant therapy [24]. MIE-PP is now widely performed and its indications are thought to be almost the same as those for OE. From a technical standpoint, it is essential to avoid intra-operative difficulties and complications. Moreover, emergency conversion to open surgery is time-consuming, especially if there is massive bleeding during MIE-PP. Thus, contra-indications for the MIE-PP procedure may include severe pleural adhesion, bulky or locally infiltrative tumors (especially those in close proximity to the trachea-bronchial tree, pulmonary vein, and aorta), and the prior use of definitive chemoradiotherapy [39, 53]. Patients with insufficient respiratory and cardiac function and morbidly obese patients were not candidates for MIE-PP.

Operative techniques

The patient is placed in a prone position after intubation using either a single-lumen endotracheal tube with a bronchial blocker or a double-lumen tube. The patients' right arm is raised cranially, and the left arm is positioned beside their body or stretched upward. Some surgeons utilize the bed rotation to set up a prone position. The operator, assistant, and an endoscopist stand on the right side of the patient, with the scrub nurse to the left and a video monitor directly opposite, on the left of the patient. This situation can be compared to that for an MIE-LP. After the patient has been placed in the correct position, the anesthesiologist

generally starts the ventilation of the left lung. Some investigators suggested that the relatively high pressure of the pneumothorax enabled them to perform MIE-PP with bilateral ventilation. The first port is inserted in the right thoracic cavity, and an artificial pneumothorax is created using carbon dioxide (CO_2) at a pressure of 6–8 mmHg. Three or four other ports are also utilized for MIE-PP. A mini-thoracotomy for the retraction of the right lung in the MIE-LP procedure is not needed for the MIE-PP procedure.

In MIE-PP, the gravity and low positive pressure in the thoracic cavity push down the organs in the middle mediastinum, such as the bronchus, trachea, and heart. Some groups have tried to make good use of this specific condition in MIE-PP and emphasize the efficacy of a preceding anterior approach [44, 53]. First, the anterior mediastinal pleura of the esophagus are incised, and the trachea and heart are shifted downward, making the dissection between the esophagus and middle mediastinal organs much easier. Next, the dissection between the esophagus and the vertebra or descending aorta is performed. The esophagus is finally mobilized from the thoracic inlet with the periesophageal mediastinal lymph nodes.

Benefits of MIE-PP

Surgical advantages

Table 1 lists the potential advantages and disadvantages of MIE-PP vs. MIE-LP. In general, the skills required to perform MIE-LP can be difficult to master [56–58]. In contrast, some investigators have suggested the possibility of a shorter learning curve for MIE-PP [37, 44]. Palanivelu et al. reported that the mean operative time for MIE-PP was shorter than that for MIE-LP performed in the same period. Fabian et al. suggested that the steepest point of the learning curve of MIE-PP is within the first five cases only. Ozawa et al. [53] and Shen et al. [54, 59] reported an obviously shorter operation time for their latter series, compared with earlier series. The effects of gravity and the CO_2 pneumothorax enable a wide surgical space. Blood pooling does not obscure the operative field and the middle mediastinal organs and right lung are naturally shifted downward during MIE-PP. MIE-PP allows for visualization of a dry and wide surgical space without the need for special assistants. Direct retraction of the right lung is not necessary in MIE-PP, whereby mechanical lung damage is avoided and the production of inflammatory mediators is decreased. Moreover, an experienced assistant is not necessarily needed to retract the respiratory organs. The fewer requirements for skilled retraction of the right lung and blood suctioning may reduce the total number of instrument changes.

Table 1 Advantages and disadvantages of performing minimally invasive esophagectomy with the patient in a prone position vs. a lateral decubitus position

Potential advantages	Potential disadvantages
Shortened learning curve	Difficulty in emergent open thoracotomy
Excellent surgical space	Limited clinical results
Experienced assistant not necessary needed	
Ergonomic position of surgical hands	
Theoretical improved arterial oxygenation	
One-lung ventilation not necessary required	

Esophagectomy is a technically meticulous procedure that inflicts a heavy physical demand on surgeons, especially when the procedure is performed thoracoscopically. The surgeon's position is very important for reducing the workload during the operation. With MIE-PP, the surgeons can operate in a relaxed and comfortable stance [36, 45, 54]. Since the surgeons can operate in a plane parallel to the camera and the ports used by the operator are located at their elbow level, the ergonomics and fatigue experienced by the surgeons may be improved by performing MIE-PP [38].

The excellent operative view, increased magnification, and better surgical ergonomics can improve the quality of mediastinal lymphadenectomy, with many surgeons emphasizing that MIE-PP enables precise dissection of the lymph nodes along the recurrent laryngeal nerves and in the aortopulmonary windows [45, 54]. The preceding anterior approach probably makes it easier to dissect the mediastinal lymph nodes. Despite the suggested difficulty of lymph node dissection along the left recurrent laryngeal nerve (RLN) during MIE-PP, surgeons have overcome this by using a single-lumen endotracheal tube with a bronchial blocker, rather than a double-lumen endotracheal tube, and rotating the trachea to expose the lymph nodes along the left RLN [44, 45].

Improvement in respiratory function

The prone position is well known to be beneficial for arterial oxygenation [60]. Several mechanisms have been suggested to explain the improvement in gas exchange while in a prone position. Changing from a supine position to a prone position redistributes the blood flow in the lungs, and pulmonary perfusion becomes more uniform [61]. A prone position also improves the diaphragm movement and increases the functional residual capacity [62]. The ventilated lung is under pressure from the mediastinum when the patient is in a decubitus position, which may increase the risk of atelectasis [63, 64]. On the other hand, almost no

lung tissue is located beneath the heart when the patient is in a prone position, and gravity moves the bronchial secretions and pulmonary extravascular fluid from the dorsal to the ventral side, allowing for the opening of bronchi that were obstructed by secretions [65, 66]. Some surgeons have been able to perform MIE-PP without the use of one-lung ventilation. The use of two-lung ventilation may reduce respiratory-related complications, but this has not been confirmed clinically.

MIE-PP can reduce the number of ports inserted and it does not require a mini-thoracotomy. Consequently, MIE-PP may result in less postoperative chest wall pain, reducing the need for strong analgesics after surgery, and it also decreases the risks of intercostal vessel injury and surgical site infection. These advantages could equate with lower levels of inflammatory response and earlier recovery of activity [67, 68].

Technical limitations of MIE-PP

The potential limitations of this technique are mainly related to intraoperative complications. The difficulty in emergency conversion to open surgery is an obvious problem, which can be related to intraoperative injury to adjacent structures. To avoid these situations, careful patient selection and precise maneuvers are essential.

The technical limitations of MIE-PP are the most likely reason why MIE-PP has not been adopted universally. To date, the majority of esophageal surgeons perform the procedure in the traditional decubitus position, and the oncologic superiority of MIE-PP over MIE-LP has not yet been confirmed. To compensate for the technical disadvantages of both MIE-PP and MIE-LP, Kaburagi et al. [69] attempted to perform MIE using a hybrid patient position, consisting of a combination of a left decubitus and prone position. This approach has been introduced only recently and its clinical utility needs to be further examined. The volume–outcome relationship in esophagectomy has been emphasized [70]. As experience performing MIE-PP increases, this procedure will become more universally accepted. Thereby, several of the problems will likely be overcome as operating teams become more familiar with MIE-PP.

Clinical results of MIE-PP

Short- and long-term outcomes

Tables 2 and 3 summarize the operative results of individual studies investigating MIE-PP and demonstrated the feasibility and safety of this technique. The conversion rate from MIE-PP to open surgery was low, and MIE-PP was completely achieved in almost all cases. The thoracoscopic operative time ranged from 68 to 307 min, and the total blood loss ranged from 50 to 700 mL. The number of lymph nodes retrieved ranged from 5 to 49. The rates of intraoperative complications associated with MIE-PP were very low. Recent studies have not reported any complications requiring conversion to open surgery. Pneumonia developed in 0–30.9 % of the patients, and recurrent laryngeal nerve palsy occurred in 0–28.6 %. The overall complication rate ranged from 13.3 to 61 %. The 30-day mortality rates associated with MIE-PP were low (0–2.4 %), with half of the studies reporting no hospital deaths. As

Table 2 Operative results of individual studies investigating minimally invasive esophagectomy in a prone position

Authors	Pts (*n*)	Conversion rate (%)	Operative time (min)	Blood loss (mL)	No. of LNs retrieved	Methods for abdomen
Palanivelu [37]	130	0	220 (160–450; total)	180 (100–400)	18 (11–32)	Lap
Smithers [42]	23	8	90 (55–120; chest)	300 (15–1000)	17 (9–33)	Lap/open
Dapri [43]	15	7	75 (60–90; chest)	700 (100–2400)	14	Lap
Fabian [44]	21	0	86 (55–138; chest)	65 (20–150; chest)	16 (7–30)	Lap
Noshiro [45]	43	0	307 ± 66 (chest)	142 ± 87	49.6 ± 16.4	Lap
Zingg [46]	56	6	250.2 (total)	320	5.7	Lap/open
Kuwabara [47]	22	5	196 (chest)	50	20.6	NA
Kim [48]	21	0	108 ± 46.3 (chest)	150 (50–2300)	11.6 ± 6.2	Lap/robot
Gao [49]	96	0	330 ± 37 (total)	347 ± 41	17.6 ± 5.6	Open
Feng [50]	52	0	67 ± 20 (chest)	123 ± 56	11.6 ± 4 (chest)	Lap
Daiko [51]	29	7	210 (130–395; chest)	527 (28–4225)	31	NA
Petri [52]	46	0	263 ± 46 (total)	140 (90–850)	13 (2–48)	Lap/open
Biere [36]	59	10	329 (90–559; total)	200 (20–1200)	20 (3–44)	Lap/open
Ozawa [53]	60	0	203 ± 52 (chest)	29 ± 52 (chest)	20.4 ± 9.3 (chest)	Lap/open
Shen [54]	35	0	68 ± 22 (chest)	89 ± 18	18.2 ± 2.9 (chest)	Lap

LNs lymph nodes, *Lap* laparoscopic, *NA* not assessed

Table 3 Morbidity and mortality of minimally invasive esophagectomy in a prone position according to individual studies

Authors	Intraoperative complication (%)	Morbidity (%)			Mortality (%)	
		Pneumonia	RLN palsy	Overall	30 day	Hospital
Palanivelu [37]	0	1.5	1.5	20.1	1.5	1.5
Smithers [42]	NA	30	0	61	0	0
Dapri [43]	20	13.3	20	NA	0	0
Fabian [44]	4.8	8	0	48	0	4.8
Noshiro [45]	2.3	11.6	14	35	2.4	2.4
Zingg [46]	3.6	30.9	NA	34.5	NA	3.6
Kuwabara [47]	4.5	4.5	22.7	27	0	0
Kim [48]	0	0	28.6	NA	0	0
Gao [49]	0	13.5	2.1	32.3	2.1	2.1
Feng [50]	0	9.6	5.8	44	0	0
Daiko [51]	6.9	3.4	17.2	31	0	NA
Petri [52]	0	15.2	2.2	36.9	0	4.4
Biere [36]	NA	8.5	2	NA	2	3
Ozawa [53]	0	13.3	10	13.3	0	0
Shen [54]	0	5.7	8.6	25.7	0	0

RLN recurrent laryngeal nerve

expected, the short-term outcome of MIE-PP is considered to be satisfactory.

On the other hand, there are few reports on the long-term outcomes following MIE-PP. In many reports, the number of patients and the follow-up periods were insufficient to analyze the survival. However, recent studies, in which the surgical procedures were performed with the patient in a decubitus position at a single institution, have shown 5-year survival rates comparable to those for a historical control and OE [28, 71–73]. Yet, no studies have reported the long-term survival after MIE-PP, and the survival outcomes after MIE-PP and MIE-LP have not been compared. These issues need to be investigated, since the question of whether MIE-PP may provide an oncological benefit to patients with esophageal cancer remains unanswered.

Comparison with OE and MIE-LP

Five reports compared surgical results of MIE-PP with those of OE (Tables 4, 5), and five other reports compared those of MIE-PP with those of MIE-LP (Tables 6, 7). Contrary to the theoretical expectation for MIE-PP, individual reports from single institutions have demonstrated that MIE-PP can be performed safely, but lack evidence that it provides a significant advantage, in terms of clinical outcome when compared with OE and MIE-LP. In our literature review, MIE-PP required a longer operative time than OE, but the blood loss was significantly lower and the number of lymph nodes retrieved was similar. Although the definitions of pneumonia and recurrent laryngeal nerve palsy were not specified, the incidences of these complications were similar for the MIE-PP and OE groups. The overall morbidity associated with MIE-PP was also comparable to that associated with OE. The 30-day mortality rates associated with MIE-PP were lower than those associated with OE, but the difference was not significant. When compared with MIE-LP, Fabian et al. [44] and Feng et al. [50] reported a shorter operative time; however, Noshiro et al. [45] reported a longer operative time for MIE-PP. The rates of conversion to open surgery, blood loss, and the number of lymph nodes retrieved were not different among the groups. Kuwabara et al. [47] reported that the incidence of pneumonia in the MIE-PP group was lower than that of the MIE-LP group. Other reports have not shown any differences in morbidity or mortality between MIE-PP and MIE-LP.

These results are most likely due to the small number of cases. Luketich et al. [71] performed more than 1000 cases of MIE-LP at one institute and reported a reliable procedure, acceptable lymph node dissection and postoperative outcomes, and a low mortality rate. MIE-PP may have a shorter learning curve [37, 44]. In fact, several reports have demonstrated a shorter operative time in their more recent series compared with earlier series [53, 54, 57]. The excellent operative view and superior ergonomics associated with MIE-PP should help to improve the clinical outcome [54]. Therefore, a large number of cases are needed to assess the true clinical utility of MIE-PP.

Because many techniques have been introduced and relatively small numbers of patients are treated in each institution, multicenter trials comparing the clinical benefits of MIE-PP and MIE-LP/OE have been difficult to perform

Table 4 Comparison of surgical results between minimally invasive esophagectomy in a prone position vs. open esophagectomy

Authors	Pts (*n*)	Operative time		Blood loss		LNs retrieved	
		(min)	*P*	(mL)	*P*	(*n*)	*P*
Smithers [42]							
MIE-PP	23	90 (55–120)[a]	0.01	300 (15–1000)	0.017	17 (9–33)	NS
OE	114	120 (60–346)[a]		600 (0–3000)		16 (1–44)	
Zingg [46]							
MIE-PP	56	250.2[b]	<0.001	320	<0.001	5.7	NS
OE	98	209.4[b]		857		6.7	
Gao [49]							
MIE-PP	96	330 ± 37[b]	<0.01	347 ± 41	<0.01	17.8 ± 5.6	NS
OE	78	284 ± 31[b]		519 ± 48		18.0 ± 6.2	
Daiko [51]							
MIE-PP	29	210 (130–395)[a]	0.0007	527 (28–4225)	NS	31	NS
OE	30	161 (90–272)[a]		495 (120–1185)		30	
Biere [36]							
MIE-PP	59	329 (90–559)[b]	0.002	200 (20–1200)	<0.001	20 (3–44)	NS
OE	56	299 (66–570)[b]		475 (50–3000)		21 (7–47)	

MIE minimally invasive esophagectomy, *PP* prone position, *OE* open esophagectomy, *NS* not significant

[a] Chest operation time

[b] Total operative time

Table 5 Comparison of morbidity and mortality between minimally invasive esophagectomy in a prone position vs. open esophagectomy

Authors	Morbidity (%)						Mortality (%)	
	Pneumonia	*P*	RLN palsy	*P*	Overall	*P*	30 day	*P*
Smithers [42]								
MIE-PP	30	NS	0	NS	61	NS	0	NS
OE	27.8		0		66.7		2.6	
Zingg [46]								
MIE-PP	30.9	NS	NA	NA	34.5	NS	3.6 (hospital)	NS
OE	38.8		NA		23.5		6.1 (hospital)	
Gao [49]								
MIE-PP	13.5	NS	2.1	NS	32.3	NS	2.1	NS
OE	14.1		5.1		46.2		3.8	
Daiko [51]								
MIE-PP	3.4	NS	17.2	NS	31	NS	0	NS
OE	3		20		40		0	
Biere [36]								
MIE-PP	8.5	0.005	2	0.012	NA	NA	2	NS
OE	28.6		14		NA		0	

MIE minimally invasive esophagectomy, *PP* prone position, *OE* open esophagectomy, *RLN* recurrent laryngeal nerve, *NS* not significant, *NA* not assessed

[74, 75]. Two recent prospective multicenter randomized trials comparing MIE with OE have been reported. The multicenter trial, known as the ECOG study [35], demonstrated that MIE is safe and feasible, with a low incidence of morbidity and mortality. The results of that trial also demonstrated that the estimated 3-year overall survival rate after MIE was similar to that for OE. Biere et al. [36] performed the thoracic part of the operation using MIE-PP and compared the short-term results to those for OE. They reported that, although the operative time was shorter for OE, MIE-PP resulted in a lower incidence of pulmonary infections and vocal cord paralysis, a shorter hospital stay, and a better short-term quality of life. The low incidence of pulmonary infection is explained by the reduction in

Table 6 Comparison of operative results between minimally invasive esophagectomy in a prone position vs. minimally invasive esophagectomy in a lateral decubitus position

Authors	MIE	Pts (*n*)	Conversion(%)	Operative time (chest)		Blood loss		LNs retrieved	
				(min)	*P*	(mL)	*P*	(*n*)	*P*
Fabian [44]	PP	21	0	86 (55–138)	0.0001	65 (20–150)[a]	NS	15.5 (7–30)	NS
	LP	11	0	123 (93–150)		80 (50–150)[a]		14.6 (6–22)	
Noshiro [45]	PP	43	0	307 ± 66	0.021	142 ± 87	0.045	49.6 ± 16.4	NS
	LP	34	5.9	272 ± 58		295 ± 416		51.2 ± 23.1	
Kuwabara [47]	PP	22	5	196 (total)	NS	50	NS	20.5	NS
	LP	58	2	205 (total)		101		18	
Feng [50]	PP	52	0	67 ± 20	0.013	123 ± 56	NS	11.6 ± 4[b]	NS
	LP	41	2.4	77 ± 17		142 ± 49		8.9 ± 4.9[b]	
Shen [54]	PP	35	0	68 ± 22	<0.001	89 ± 18	<0.001	18.2 ± 2.9[b]	<0.001
	LP	32	0	87 ± 24		67 ± 16		15.4 ± 3.3[b]	

MIE minimally invasive esophagectomy, *PP* prone position, *LP* lateral decubitus position, *NS* not significant

[a] Chest

[b] Total operative time

Table 7 Comparison of morbidity and mortality between minimally invasive esophagectomy in a prone position vs. minimally invasive esophagectomy in a lateral decubitus position

Authors	MIE	Intraope. complication		Morbidity (%)						Mortality (%)	
		(%)	*P*	Pneumonia	*P*	RLN palsy	*P*	Overall	*P*	Hospital	*P*
Fabian [44]	PP	4.8	NS	8	NS	0	NS	48	NS	4.8	NS
	LP	9.1		9.1		9.1		55		0	
Noshiro [45]	PP	2.3	NS	11.6	NS	14	NS	35	NS	2.4 (30 day)	NS
	LP	5.9		14.7		17.6		35.3		0 (30 day)	
Kuwabara [47]	PP	4.5	NS	4.5	<0.05	22.7	NS	27	NS	0	NS
	LP	1.7		29.3		34.5		44.8		3.4	
Feng [50]	PP	0	NS	9.6	NS	5.8	NS	44	NS	0	NS
	LP	0		7.3		2.4		48.8		2.4	
Shen [54]	PP	0	NS	5.7	NS	8.6	NS	25.7	NS	0	NS
	LP	0		12.5		6.3		31.3		0	

MIE minimally invasive esophagectomy, *PP* prone position, *LP* lateral decubitus position, *RLN* recurrent laryngeal nerve, *NS* not significant

atelectasis after esophagectomy. This study confirmed the theoretical advantages of MIE-PP compared with those of OE and also the short-term benefits suggested by previous nonrandomized studies. The benefits of long-term survival after MIE-PP should be investigated further.

Conclusions

The introduction of MIE as a thoracoscopic approach marked the beginning of a new epoch in esophagectomy. Many esophageal surgeons are interested in adopting MIE because it has the potential to lower morbidity and to allow a quicker postoperative return to normal function. To date, there are two standard approaches for MIE: the left decubitus position, and the prone position. Until recently, MIE-LP was used exclusively; however, a good surgical space can be difficult to maintain during MIE-LP and special assistants are required for this procedure. To compensate these disadvantages of MIE-LP, esophageal surgeons attempted MIE-PP as a standard procedure for esophageal cancer. MIE-PP may be beneficial to both surgeons and patients, in terms of excellent operative view, superior ergonomics, and improved gas oxygenation. Our review compared MIE-PP with both MIE-LP and OE. Contrary to the theoretical superiority of MIE-PP, individual reports from single institutions, with a small number of patients and short follow-up periods have not demonstrated the significant advantages of

clinical outcome in their MIE-PP groups vs. their MIE-LP and OE groups. Few studies have been able to report on the long-term survival after MIE-PP, and the survival outcomes after MIE-PP vs. MIE-LP have not been compared. Therefore, both, a large number of cases and longer term follow-up are needed to assess the oncological benefit of MIE-PP for patients with esophageal cancer.

In conclusion, evidence supports that MIE-PP is a safe and feasible procedure for esophageal cancer; however, further clinical studies are required to establish whether the possible advantages of MIE-PP can be translated into an improved postoperative outcome.

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