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Review Article

Surgical Benefits of Prone Position Thoracoscopic Esophagectomy Over Open Thoracic and Thoracoscopic Esophagectomy in Left Lateral Decubitus Position: A Literature Review

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ABSTRACT

Objective: We reviewed the surgical outcomes of minimally invasive esophagectomy (MIE), especially the number of lymph nodes retrieved, for the patients with esophageal cancer to clarify the surgical benefits of MIE in patients with esophageal cancer.

Material and Methods: A systematic literature search was performed, and articles that fully described the surgical results of MIE were selected. Parameters such as operative time, blood loss, the number of lymph nodes retrieved, and postoperative complications were compared among patients undergoing minimally invasive esophagectomy (MIE) in the left lateral decubitus position (MIE-LP), MIE in the prone position (MIE-PP), and open thoracic esophagectomy (OE).

Results: The conversion rate from MIE to OE was very low. MIE-PP was associated with lower blood loss than OE and MIE-LP. Results of a multicenter randomized controlled trial demonstrated that pneumonia and recurrent laryngeal nerve paralysis in MIE-PP significantly reduced compared with OE. Although postoperative complications were not different between MIE-PP and MIE-LP, the number of lymph nodes retrieved in MIE-PP was higher than that in MIE-LP.

Conclusion: MIE-PP has potential benefits in terms of less surgical invasiveness and improvement of mediastinal lymph node dissection. A prospective randomized control trial using a large number of cases and long-term follow-up is recommended for analyses of appropriate mediastinal lymph node dissection and its impact on oncological benefit.

Introduction

The incidence of esophageal cancer has been increasing over the past two decades [1, 2]. Esophagectomy with regional lymph node dissection still remains the mainstay of curative modality for patients with localized thoracic esophageal cancer [3-6]. However, morbidity is a major concern during the follow-up period because of the invasive nature of esophagectomy and the complex operative procedures involved [7-9].

A thoracoscopic approach has been attracting attention as a minimally invasive technique, because this approach has the potential to lower morbidity and to enable a more rapid return to normal function after esophageal surgery [10, 11]. Since Cuschieri *et al*. first reported on thoracoscopic minimally invasive esophagectomy (MIE) for the treatment of esophageal cancer in 1992, several surgeons performed and demonstrated safety and feasibility of the technique by the late 1990s [12-19]. After these exploratory investigations, the number of MIE procedures being performed has been increasing, and reports from large single-center studies began to reveal improvements in surgical outcomes of MIE [20-24]. Recent meta-analyses using individual institutional reports showed that, compared with open transthoracic esophagectomy (OE), MIE was associated with less operative blood loss, shorter length of intensive care unit (ICU) and hospital stays, and reduced incidence of postoperative respiratory complications [25-29].

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On the other hand, results from several nationwide database analyses have been disappointing, and have demonstrated that MIE did not reduce postoperative respiratory complications and had higher reoperation or reintervention rates [30-32]. These unexpected results of the nationwide database analyses may be attributable to the inclusion of a wide range of patients, surgeons, and hospitals. Furthermore, apparent variations in surgical technique for esophagectomy between Eastern and Western countries are also considered when investigators compare the surgical outcomes between MIE and OE.

To clarify the surgical benefits of MIE in the patient with esophageal cancer, we reviewed the currently available literature regarding oncological comparisons between MIE and OE. MIE was divided further into two groups according to the patient position during MIE: MIE performed in the left lateral position (MIE-LP) and prone position (MIE-PP). Accordingly, we compared the surgical outcomes, including the number of lymph nodes retrieved and postoperative complications, among the MIE-LP, MIE-PP, and OE groups.

Literature Search

A literature search of PubMed databases was performed using "esophagectomy," "thoracoscopic," "thoracoscopy," "minimally invasive," "MIE," "VATS," and "esophageal cancer" as keywords. The search was expanded to include the reference articles mentioned in each report. After identifying suitable articles by title, we read the abstracts of these studies to determine the eligibility, and then we selected articles investigating the correlation between MIE-LP and MIE-PP as well as between OE and MIE. We retrieved full manuscripts, and articles in which only laparoscopic gastric mobilization or transhiatal resection using mediastinoscopy and/or laparoscopy was performed as minimally invasive surgery were excluded. In other words, we defined thoracoscopic esophageal mobilization and mediastinal lymph node dissection as MIE in the study. We further selected articles in which surgical results, such as operative time, blood loss, number of lymph nodes retrieved, and short-term surgical outcomes, were described. In particular, a description about the number of lymph nodes retrieved was absolutely required in the selected articles. When the investigators described overlapping results obtained from the same patients but published in different reports, only the most recent article was selected.

Patient Selection for MIE

Currently, two standard procedures, MIE-LP and MIE-PP, are being performed by different surgeons and at different institutions. MIE had been performed exclusively while the patient was in the LP. MIE-LP requires total collapse and retraction of the lung and also a special team consisting of an expert surgeon and expert assistant. In 2006, Palanivelu *et al*. reported on a large number of MIE procedures that were performed while the patient was in the PP [33]. Due to the excellent exposure of the operative field and better ergonomics of the surgeon's stance, MIE-PP has become a popular approach for patients with esophageal cancer [34]. The indications for MIE-PP are similar to those for MIE-LP. Initially, from a technical standpoint, the avoidance of intraoperative difficulties and complications is essential. Emergent conversion to open surgery is time-consuming, especially in cases with massive bleeding. Thus, contraindications for the MIE 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 prior use of definitive chemoradiotherapy [35, 36]. Also, patients with insufficient respiratory and cardiac function or morbid obesity were not candidates for MIE.

Table 1: Comparison of surgical results between MIE-LP and OE.

Author		Pts	Operative time (chest)		Blood loss		LNs retrieved		Conversion
		(n)	(min)	*P*	(mL)	*P*	(n)	*P*	(%)
Osugi [37]	LP	77	227±80	0.031	284±80	0.99	33.9±12.0	0.90	NA
	OE	72	186±35		310±170		32.8±14.0		–
Kunisaki [38]	LP	15	301±68	<0.001	448±215	0.042	24.5±10.0	0.53	NA
	OE	30	258±62		675±446		26.6±10.4		–
Parameswaran [39]	LP	50	442 (305-508)¶	<0.01	NA	NA	23 (7-49)	<0.001	NA
	OE	30	266 (219-390)¶		NA		10 (2-23)		–
Schoppmann [40]	LP	31	411 (270-600)¶	0.69	NA	NA	17.9±7.7	0.65	NA
	OE	62	400 (240-550)¶		NA		20.5±12.6		–
Pham [41]	LP	44	543±72.6¶	<0.01	407±267	<0.01	13 (9-15)	<0.01	NA
	OE	46	437±97.0¶		780±610		8 (3-14)		–
Berger [42]	LP	65	NA	NA	182	<0.001	20	<0.001	NA
	OE	53	NA		619		9		–
Nafteux [43]	LP	65	375±87¶	0.001	290±568	0.01	14.4±8.2	0.23	12.2
	OE	101	322±72¶		491±439		19.8±17.9		–
Sundaram [44]	LP	47	420 (310-500)¶	<0.001	500 (300-750)	0.01	20 (14-27)	NS	NA
	OE	26	480 (420-600)¶		800 (550-1200)		19 (15-25)		–
Sihag [45]	LP	38	360 (318-391)¶	0.54	200 (150-250)	<0.001	19 (15-28)	0.74	NA
	OE	76	365 (316-441)¶		250 (200-400)		21 (16-27)		–

MIE: minimally invasive esophagectomy; LP: left lateral decubitus position; OE: open esophagectomy; NS: not significant; NA: not assessed; ¶total operative time.

Table 2: Comparison of morbidity and mortality between MIE-LP and OE.

Author		Morbidity (%)								Mortality	
		Pneumonia	*P*	RLNP	*P*	Leak	*P*	Any	*P*	(%)	*P*
Osugi [37]	LP	15.5	0.67	14.3	0.81	1.3	0.20	38.6	NS	0	NS
	OE	19.4		12.5		5.6		32.4		0	
Kunisaki [38]	LP	0	0.48	20	0.35	6.7	0.20	NA	NA	0	1.0
	OE	3.3		10		3.3		NA		0	
Parameswaran [39]	LP	8	0.05	12	0.07	8	0.52	48	NS	2	NS
	OE	23		0		3		50		3	
Schoppmann [40]	LP	6.2	0.003	2.9	0.005	3.2	0.024	35.5	0.002	0	1.0
	OE	35.5		41.9		25.8		74.2		0	
Pham [41]	LP	25	0.30	14	0.06	9	0.78	77	0.06	6.8	0.34
	OE	15		0		11		59		4.3	
Berger [42]	LP	7.7	0.11	NA	NA	14	1.0	48	0.1	7.7	1.0
	OE	18		NA		11		60		7.5	
Nafteux [43]	LP	26.2	0.005	NA	NA	9.9	0.63	67.3	0.34	3.1	0.66
	OE	46.5		NA		7.7		60.4		2.0	
Sundaram [44]	LP	10.6	0.013	0	0.67	8.5	0.18	59.5	NS	4.25	0.58
	OE	34.6		2.13		0		53.9		0	
Sihag [45]	LP	0	0.001	NA	NA	0	0.55	NA	NA	0	0.55
	OE	21.0		NA		2.6		NA		2.6	

MIE: minimally invasive esophagectomy; LP:left lateral decubitus position; OE: open esophagectomy; RNLP: recurrent laryngeal nerve paralysis; NS: not significant; NA: not assessed.

Comparison of Surgical Outcomes between MIE-LP and OE

Nine studies could compare their results between OE and MIE-LP (Tables 1 & 2) [37-45]. In the literature review, MIE-LP required a longer operative time compared with OE; however, blood loss was significantly lower. The increased magnified view allows surgeons to perform fine surgical procedures and ensure hemostasis. On the other hand, thoracoscopic surgery, while watching the magnified monitors, requires special techniques to perform the surgical procedures. In general, the skills required to perform MIE can be difficult to master; consequently, the operative time is longer [46-48]. Sundaram *et al*. found that operative time decreased with increasing experience when they compartmentalized MIE-LP into sequential groups, and they demonstrated significantly shorter operative times in the MIE-LP group compared with the OE groups, which could be secondary to a learning curve [44]. Shorter operative time and reduced blood loss can be attained with increasing experience, and this may be associated with precise dissection of the lymph nodes and lower incidence of postoperative complications [37, 38, 49].

The number of lymph nodes retrieved was not different between MIE-LP and OE; thus, showing that MIE-LP was oncologically equivalent to OE. The tracheobronchial tree can be easily retracted ventrally to visualize the left side of the trachea during OE. However, retractors introduced through a thoracoscopic port may not be effective in some cases, resulting in difficulty in access to the left paratracheal and infra-aortic nodes [50]. Several reports demonstrated that MIE-LP produced a significantly higher incidence of lymph node dissection than OE. It is likely due to the improvement of the operative technique.

Although the definitions of pneumonia were not specified and considerable variations in the incidence of pneumonia have been reported, several reports have demonstrated a trend towards decreased rates of pulmonary complications with MIE-LP. Esophagectomy that involves a thoracotomy incision is associated particularly with a significant risk of pulmonary complications. MIE could minimize the surgical wound and reduce postoperative pain, and these factors might be considered as advantages reducing the incidence of pneumonia after esophagectomy. Furthermore, Osugi *et al*. demonstrated that MIE could maintain respiratory function: vital capacity reduction was less with MIE-LP than with OE [37]. RLN paralysis (RLNP) is a common and sometimes severe complication after esophagectomy [51]. MIE has a possible advantage in reducing RLNP because of the magnified view provided by thoracoscopy. However, contrary to expectation, individual reports could not demonstrate a decreased incidence of RLNP after MIE-LP. Schoppmann *et al*. [40] demonstrated a significantly lower incidence of RLNP in MIE-LP. However, in their study, intrathoracic anastomosis was used favorably in MIE-LP, while, on the other hand, cervical anastomosis was performed in the majority of OE patients. Accordingly, the role of MIE-LP in preserving RLN function remains controversial.

Mortality after MIE-LP was very low and comparable to that after OE. MIE-LP could be performed safely: half of the studies reported no hospital deaths after MIE-LP. Thus, the short-term outcome of MIE-LP is considered to be satisfied, as expected.

Comparison of Surgical Outcomes between MIE-PP and OE

Eight studies could compare their results between OE and MIE-PP (Tables 3 & 4) [52-59]. Similar to the comparison between OE and MIE-LP, almost all studies reported significantly longer operative time for

MIE-PP compared with OE. However, this might be owing to the learning curve of performing MIE-PP. In fact, operative time for MIE-PP was relatively shorter than that for MIE-LP. Some investigators have suggested the possibility of a shorter learning curve for MIE-PP [60, 61].

Ozawa *et al*. and Shen *et al*. demonstrated an obviously shorter operation time for their latter series, compared with earlier series [36, 62]. Significantly reduced blood loss was observed in MIE-PP. Lower blood loss is reflected by fewer patients requiring blood transfusion.

Table 3: Comparison of surgical results between MIE-PP and OE.

Author		Pts	Operative time (chest)		Blood loss		LNs retrieved		Conversion
		(n)	(min)	*P*	(mL)	*P*	(n)	*P*	(%)
Smithers [53]	PP	23	90 (55-120)	0.01	300 (15-1000)	0.017	17 (9-33)	NS	3
	OE	114	120 (60-346)		600 (0-3000)		16 (1-44)		–
Zingg [54]	PP	56	250.2±7.2¶	<0.001	320±49	<0.001	5.7±0.4	0.14	5.5
	OE	98	209.4±7.8¶		857±82		6.7±0.5		–
Gao [55]	PP	96	330±37¶	<0.01	347±41	<0.01	17.8±5.6	NS	0
	OE	78	284±31¶		519±48		18.0±6.2		–
Daiko [56]	PP	29	210 (130-395)	<0.001	527 (28-4225)	0.83	23 (4-39)†	0.66	6.9
	OE	30	161 (90-272)		495 (120-1185)		22 (4-38)†		–
Yatabe [57]	PP	24	640±85¶	0.01	209±146	0.002	44±14	0.88	0
	OE	24	576±82¶		474±279		43±15		–
Iwahashi [58]	PP	46	362±40	<0.001	125 (30-420)	<0.001	23 (9-36)†	0.77	0
	OE	46	234±44		255 (72-925)		22 (9-54)†		–
Bonavina [52]	PP	80	330 (302-368)¶	<0.01	295 (250-335)	0.08	32 (29-43)	0.68	0
	OE	80	300 (270-338)¶		300 (275-340)		34 (28-45)		–
Biere [59]	PP	59	329 (90-559)¶	0.002	200 (20-1200)	<0.001	20 (3-44)	0.85	14
	OE	56	299 (66-570)¶		475 (50-3000)		21 (7-47)		–

MIE: minimally invasive esophagectomy; PP: prone position; OE: open esophagectomy; NS: not significant; NA: not assessed; ¶total operative time; †chest.

Table 4: Comparison of morbidity and mortality between MIE-PP and OE.

Author		Morbidity (%)								Mortality (%)	
		Pneumonia	*P*	RLNP	*P*	Leak	*P*	Any	*P*	(%)	*P*
Smithers [53]	PP	30	NS	0	NS†	4	NS	61	NS	0	NS
	OE	27.8		0		8.7		66.7		2.6	
Zingg [54]	PP	30.9	0.34	NA	NA	20.0	0.34	34.5	0.16	3.6	0.47
	OE	38.8		NA		12.8		23.5		6.1	
Gao [55]	PP	13.5	NS	2.1	NS	7.3	NS	32.3	NS	2.1	NS
	OE	14.1		5.1		7.7		46.2		3.8	
Daiko [56]	PP	3.4	1.0	17.2	1.0	14	0.71	31	0.59	0	NS
	OE	3		20		10		40		0	
Yatabe [57]	PP	4	0.003	8	0.22	13	0.68	25	0.02	4	0.24
	OE	38		21		17		58		0	
Iwahashi [58]	PP	2.2	0.5	10.9	1	2.2	0.18	13.0	0.02	0	1
	OE	4.3		10.9		8.7		30.4		0	
Bonavina [52]	PP	13.7	0.64	NA	NA	13.7	0.82	NA	NA	3.7	0.68
	OE	11.3		NA		12.5		NA		2.5	
Biere [59]	PP	8.5	0.005	2	0.012	12	0.39	NA	NA	3	0.59
	OE	28.6		14		7		NA		1	

MIE: minimally invasive esophagectomy; PP: prone position; OE: open esophagectomy; RNLP: recurrent laryngeal nerve paralysis; NS: not significant; NA: not assessed.

There were no significant differences in the number of lymph nodes retrieved between OE and MIE-PP. Biere *et al*. conducted a randomized control trial and also showed the same results as reports from individual institutions [59]. Thus, these findings demonstrated that MIE-PP achieved comparable oncological lymph node dissection, as did OE. Lymph node dissection along the left RLN in MIE-PP had been thought to be difficult; however, the combination of gravity with retraction of the esophagus can create the satisfactory operative field at the left side of the tracheobronchial tree [63]. Shen *et al*. and Oshikiri *et al*. described a learning curve regarding mediastinal lymph node dissection in MIE-PP, and more experience was associated with more numbers of dissected lymph nodes without increasing morbidity, especially RLNP [62, 64]. The number of lymph nodes retrieved was relatively higher in Eastern than in Western countries. This might be influenced by the difference in

the extent of lymph node dissection according to the surgical procedures, such as three-field versus Ivor-Lewis procedures.

MIE-PP has been considered beneficial for reducing postoperative respiratory complications and improving postoperative respiratory function. Direct retraction of the right lung is not necessary in MIE-PP, and this enables mechanical lung damage to be avoided and decreases the production of inflammatory mediators. However, pneumonia did not decrease in MIE-PP compared with OE in reports from individual institutions. These unexpected findings might be related to unspecified definitions of pneumonia and relatively small numbers of patients in individual studies [65, 66]. In fact, a randomized control trial demonstrated a significantly lower incidence of pneumonia after MIE-PP than OE, which consequently proved the theoretical advantages of MIE-PP [59].

Previous reports have suggested that upper thoracic tumor location, suprabifurcational lymph node dissection, and cervical esophagogastric anastomosis may increase the incidence of RLNP [67]. We previously demonstrated that longer operative time is independently associated with RLNP [51]. Although individual studies could not show any difference in the incidence of RLNP between OE and MIE-PP, Biere *et al*. revealed a significantly lower incidence of RLNP after MIE-PP in their randomized trial, despite performing cervical anastomosis and a longer operative time for MIE-PP. These findings also prove the theoretical advantages of MIE-PP, in which surgeons can dissect the lymph nodes along the RLN safely and precisely under the magnified view. The mortality for MIE-PP was very low and comparable to that for OE. Thus, the short-term outcome of MIE-PP is considered to be satisfied.

Table 5: Comparison of surgical results between MIE-PP and -LP.

Author	MIE	Pts	Operative time (chest)		Blood loss		LNs retrieved		Conversion
		(n)	(min)	*P*	(mL)	*P*	(n)	*P*	(%)
Fabian [69]	PP	21	86 (55-138)	0.0001	65 (20-150)	0.14	15.5 (7-30)	0.69	0
	LP	11	123 (93-150)		80 (50-150)		14.6 (6-22)		0
Kuwabara [70]	PP	22	196	NS	50	NS	20.5	NS	5
	LP	58	205		101		18		2
Feng [71]	PP	52	67±20	0.013	123±56	0.11	11.6±4	0.005	0
	LP	41	77±17		142±49		8.9±4.9		2.4
Shen [68]	PP	35	68±22	<0.001	89±18	<0.001	18.2±2.9	<0.001	0
	LP	32	87±24		67±16		15.4±3.3		0
Noshiro [72]	PP	74	310±67	<0.001	186±115	<0.001	48.7±18.0	0.20	0
	LP	146	242±56		517±406		45.1±21.5		2.7
Ours	PP	67	263 (211–441)	0.76	25 (5–263)	0.002	46 ± 19	0.015	2.9
	LP	37	272 (221–368)		229 (10–370)		40 ± 19		0

MIE: minimally invasive esophagectomy; PP: prone position; LP: left lateral decubitus position; NS: not significant.

Table 6: Comparison of morbidity and mortality between MIE-PP and -LP.

Author		Intraoperative complication		Morbidity (%)							Mortality	
		(%)	*P*	Pneumonia	*P*	RLNP	*P*	Leak	*P*	Any	*P*	(%)	*P*
Fabian [69]	PP	4.8	NS	8	NS	0	NS	4	NS	48	NS	4.8	1
	LP	9.1		9.1		9.1		18		55		0	
Kuwabara [70]	PP	4.5	NS	4.5	<0.05	22.7	NS	14	NS	27	NS	0	NS
	LP	1.7		29.3		34.5		26		44.8		3.4	
Feng [71]	PP	0	NS	9.6	1	5.8	0.63	7.7	0.049	44	0.66	0	NS
	LP	0		7.3		2.4		22.0		48.8		2.4	
Shen [68]	PP	0	NS	5.7	0.59	8.6	0.92	8.6	0.75	25.7	0.62	0	NS
	LP	0		12.5		6.3		9.4		31.3		0	
Noshiro [72]	PP	1.4	NS	22	0.59	24	0.06	5	0.44	41	0.89	1	NS
	LP	0		18		14		10		41		1	
Ours	PP	0	NS	7.5	0.02	19.4	0.69	7.5	0.56	38.8	0.66	3	0.18
	LP	0		24.3		16.2		10.8		43.2		0	

MIE: minimally invasive esophagectomy; PP: prone position; LP: left lateral decubitus position; RNLP: recurrent laryngeal nerve paralysis; NS: not significant

Comparison of Surgical Outcomes between MIE-PP and MIE-LP

Five studies compared their results between MIE-PP and MIE-LP (Tables 5 & 6) [68-72]. Despite the limitations based on study design, such as patient bias, these head-to-head comparisons have proved the theoretical advantages of the PP. In the PP, bleeding pools outside of the operative field, and consequently, operative time can be reduced. Without the need for a skilled assistant to provide retraction or to expose the operative fields, surgeons are able to perform precise dissections in a more efficient fashion. In particular, MIE-PP has an advantage when upper mediastinal lymph node dissection is performed. As expected, in MIE-PP, the number of lymph nodes retrieved was higher without increasing the incidence of RLNP when compared with MIE-LP.

The PP is well known to have beneficial effects on arterial oxygenation [73]. Several mechanisms explaining improvement in gas exchange while in a PP have been suggested. As expected, in MIE-PP, the incidence of pneumonia in MIE-PP showed a trend of lower incidence compared with that in MIE-LP. Other intraoperative complications and mortality rates of MIE-PP were comparable to those of MIE-LP.

Conclusion

To date, there are two standard approaches for MIE: MIE-LP and MIE-PP. However, MIE-PP seems to have potential benefits in terms of less surgical invasiveness and improvement of mediastinal lymph node dissection. A prospective randomized control trial using the large number of cases and long-term follow-up is recommended for analyses of appropriate mediastinal lymph node dissection and its impact on oncological benefit.

Conflicts of Interest

None.

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