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Original Article

Effects of laparo-thoracoscopic surgery and open surgery on pulmonary infection in elderly patients with esophageal cancer

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Abstract: Objective: We aimed to investigate the effects of two different surgical methods, laparo-thoracoscopic minimally invasive surgery and traditional open surgery, on postoperative pulmonary infection in elderly patients with esophageal cancer. Methods: Eighty elderly patients with esophageal cancer treated between October 2013 and April 2016 were chosen, and they were divided into a laparo-thoracoscopic minimally invasive surgery group (n=40 cases) and an open surgery group (n=40 cases). Within each group, surgery status, postoperative pulmonary complications and changes in patients' pulmonary function were observed and statistically analyzed. Results: The incidence rate of postoperative pulmonary complications (pulmonary infections, atelectasis, acute respiratory distress syndrome (ARDS), pulmonary embolism, respiratory failure, pleural effusion) in the minimally invasive group was lower than that in the open surgery group. The postoperative values for forced expiratory volume in 1 s (FEV1), forced vital capacity (FVC), arterial oxygen partial pressure (PaO_2) and arterial oxygen saturation (SaO_2) within both groups were all lower than the corresponding preoperative values, but the decrement in the minimally invasive group was significantly smaller than that observed in the open surgery group. Conclusion: Laparo-thoracoscopic minimally invasive surgery can effectively protect pulmonary function, reduce the incidence of postoperative pulmonary complications, and improve surgical efficacy among elderly patients with esophageal cancer.

Keywords: Esophageal cancer, minimally invasive surgery, pulmonary infection, elderly patients

Introduction

Esophageal cancer is a common malignancy with a mortality rate that is second only to gastric cancer. China has a high-incidence of esophageal cancer. Due to increases in life expectancy, the proportion of elderly patients in the total population is growing [1]. At present, surgery is the major treatment method for esophageal cancer. However, elderly patients are likely to have poor health conditions and more preoperative complications; in addition, surgical trauma and postoperative pain tend to lead to postoperative pulmonary infection, respiratory dysfunction and other serious complications, which affect the postoperative prognosis and may lead to death in severe cases [2-3]. Therefore, choosing an appropriate surgical method for elderly patients with esophageal cancer could significantly improve therapeutic efficacy and reduce postoperative complications. In recent years, the use of laparo-thoracoscopic minimally invasive surgery for esophageal cancer has been increasingly promoted; however, pulmonary infection is still one of its main complications [4]. In this study, we investigate the effects of two different surgical methods, laparo-thoracoscopic minimally invasive surgery and traditional open surgery, on the incidence of postoperative pulmonary infection in elderly patients with esophageal cancer to provide a reference for selecting more appropriate surgical methods and improving surgical efficacy.

Patients and methods

Patient information

Eighty elderly patients with esophageal cancer treated between October 2013 and April 2016 in our department were selected, and they were divided into a laparo-thoracoscopic minimally invasive surgery group (40 cases) and an open surgery group (40 cases). The laparo-thoracoscopic surgery group had 32 males and eight females, with an average age of 67 ± 4.5 years. The open surgery group had 34 males and six females, with an average age of 66 ± 3.7 years. The criteria for patients inclusion: 1. more than 60 years old; 2. pathologically diagnosed as esophageal cancer; 3. without obvious operation risk. All patients were diagnosed with esophageal cancer by preoperative gastroscopic pathology. Conventional preoperative ultrasonography, computed tomography (CT), and other imaging examinations suggested that the included patients did not have significant local invasions, distant metastasis, enlarged mediastinal lymph nodes, or major organ dysfunction. Patients in the laparo-thoracoscopic surgery group underwent combined laparo-thoracoscopic radical esophagectomy, while patients in the open surgery group underwent radical esophagectomy via three incisions in the right thorax, abdominal middle line and left neck.

Surgical procedures

Combined laparo-thoracoscopic radical esophagectomy: After the patient was given satisfactory general anesthesia, double-lumen endotracheal intubation was performed. The patient took the left prone position, and the artificial pneumothorax was established. The thoracoscope was used to dissect the thoracic esophagus and thoracic lymph nodes. Then, the patient took the supine position, and the laparoscope was used to mobilize the stomach and dissect the abdominal lymph nodes. The laparoscopic opening entered the abdomen by extending 5 cm below the xiphoid process in the upper abdomen, and the esophagus was cut off at the junction of the esophagus and the stomach. The stomach was taken out and made into a tubular stomach. An incision was made at the front edge of the left sternocleidomastoid, and the esophagus was resected. Finally, anastomosis of the tubular stomach and cervical esophagus was conducted with a disposable stapler.

Radical esophagectomy via three incisions in the right thorax, abdominal middle line and left neck: After the patient was given satisfactory general anesthesia, double-lumen endotracheal intubation was performed. The patient took the left lateral position, and a 15-20 cm posterolateral incision was made via the fifth intercostal space. The thoracic esophagus was mobilized, and the mediastinal lymph nodes were dissected. After the chest was closed, the patient took the supine position. An incision was made in the abdominal middle line, the entire stomach was mobilized, and the lymph nodes around the stomach were dissected. The esophagus was cut off at the junction of the esophagus and the stomach, and the stomach was made into a tubular stomach with a width of approximately 4 cm. An incision was made at the front edge of the left sternocleidomastoid, and the esophagus was resected. Finally, anastomosis of the tubular stomach and cervical esophagus was conducted with a disposable stapler.

Observation parameters

The intraoperative and postoperative conditions, including operation time, blood loss, number of intraoperatively dissected lymph nodes, number of days of postoperative thoracic drainage, postoperative hospitalization time, postoperative pain and postoperative complications of the patients in both groups were analyzed. Postoperative pain was evaluated using the visual analog scale (VAS) of pain [5], and this evaluation was normally conducted 72 hours after surgery. All patients underwent routine preoperative pulmonary function tests and blood gas analysis, and by the 5th day after the surgery, the pulmonary function tests and blood gas analysis were conducted again. Pulmonary function tests included forced expiratory volume in 1 s (FEV1), forced vital capacity (FVC), arterial oxygen partial pressure (PaO_2) and arterial oxygen saturation (SaO_2).

Diagnosis of pulmonary complications

The diagnosis criteria of pulmonary complications referred to [6]. (1) Atelectasis was indicated by chest CT examination suggesting atelectasis above the lobes. (2) Pulmonary infection was diagnosed in cases of cough, coughing up phlegm, positive sputum bacterial culture, and when other causes of infection were excluded. (3) Acute respiratory distress syndrome (ARDS) was indicated in patients who breathed at 30

Table 1. General patient characteristics

Parameters	Minimally invasive surgery group (n=40)	Open surgery group (n=40)	P
Gender (male/female)	32 (80)/8 (20)	34 (85)/6 (15)	0.556
Age (years)	67 ± 4.5	66 ± 3.7	0.571
Tumor location			0.807
Upper	4 (10)	3 (7.5)	
Middle	27 (67.5)	29 (72.5)	
Lower	9 (22.5)	8 (20)	
TNM staging			1
I	10 (25)	7 (17.5)	
II	19 (47.5)	17 (42.5)	
III	11 (27.5)	14 (35)	
IV	0 (0)	2 (5)	
Hypertension	9 (22.5)	8 (20)	0.784
Diabetes	7 (17.5)	8 (20)	0.774
Smoking history	28 (70)	23 (57.5)	0.244

times/min and also had wheezing, imaging suggesting a bilateral lung infiltration shadow, and blood gas analysis suggestive of hypoxemia. (4) Respiratory failure was diagnosed if postoperative ventilator support was needed and the patient could not breathe spontaneously without the ventilator within the 24 hours following operation.

Statistical analysis

SPSS 18.0 statistical software was used. Measurement data were represented by the means ± standard deviation.The t student test was used to analyze quantitative variables, while the chi-squared test was used for the qualitative ones. A value for *P*<0.05 indicates a statistically significant difference.

Results

Demographic and pathologic data: minimally invasive surgery group vs. open surgerygroup (Supplementary Table 1)

The patients in the two groups were compared regarding gender, age, tumor location, tumor-node-metastasis (TNM) staging, hypertension, diabetes, and smoking history; none of these characteristics were significantly different between the groups (P>0.05), and all mean values were comparable. Patients older than 60 years of age were considered elderly patients. Patients' esophageal tumors were mostly in the middle segment of the esophagus and were least frequently in the upper segment (**Table 1**).

Intraoperative and postoperative complications: minimally invasive group vs. open group (Supplementary Table 2)

The average operation time for the minimally invasive surgery group was shorter than that for the open surgery group. Intraoperative blood loss within the minimally invasive surgery group was significantly less than that in the open surgery group. The postoperative closed-chest drainage time of the minimally invasive surgery group was shorter than that of the open surgery group. The number of days of postoperative hospitalization of the minimally invasive surgery group was lower than that of the open surgery group. The postoperative pain score of the minimally invasive surgery group was significantly superior to that of the open surgery group (P<0.05). The incidence of recurrent laryngeal nerve injury in the minimally invasive surgery group was higher than in the open surgery group (P>0.05). The incidence rate of postoperative atelectasis, ARDS, pulmonary embolism, respiratory failure and pleural effusion within the minimally invasive surgery group was significantly lower than that in the open surgery group, suggesting that minimally invasive surgery could substantially lower postoperative pulmonary complications. However, this difference did not reach statistical significance (P>0.05). We believe that this was due to an insufficient number of cases. The intraoperative lymph node dissection number, recurrent laryngeal nerve injury, and the incidence of postoperative anastomotic fistula within the minimally invasive surgery group were essentially the same as the corresponding values in the open surgery group, and the comparison between the two groups for these factors did not reach statistical significance (P>0.05). The occurrence of postoperative pulmonary infection in the minimally invasive surgery group was significantly lower than that in the open surgery group, and this comparison was statistically significant (P<0.05) (**Table 2**).

Table 2. Intraoperative and postoperative complications

Parameters	Minimally invasive surgery group (n=40)	Open surgery group (n=40)	P
Operation time (min)	294.5 ± 30.2	341.7 ± 24.6	0.000
Intraoperative blood loss (ml)	204.2 ± 29.3	490 ± 31.5	0.000
Lymph node dissection	14.3 ± 2.5	15 ± 3	0.844
Days of postoperative chest drainage	5.3 ± 1.5	6.5 ± 2.2	0.001
Days of hospitalization	10.3 ± 2.5	12.8 ± 2.6	0.000
Postoperative pain scores	1.3 ± 0.4	2.6 ± 0.7	0.000
Recurrent laryngeal nerve injury	2 (5)	1 (2.5)	0.556
Anastomotic fistula	4 (10)	5 (12.5)	0.723
Pulmonary infection	7 (17.5)	15 (37.5)	0.045
Atelectasis	6 (15)	9 (22.5)	0.390
ARDS	5 (12.5)	10 (25)	0.152
Pulmonary embolism	0 (0)	2 (5)	0.152
Respiratory failure	1 (2.5)	2 (5)	0.556
Pleural effusion	6 (15)	13 (26)	0.065

Table 3. Preoperative and postoperative changes in pulmonary function and blood gas

Parameters		Minimally invasive surgery group (n=40)	Open surgery group (n=40)	P
FEV1	Preoperative	2.87 ± 0.26	2.78 ± 0.25	0.067
	Postoperative	2.19 ± 0.31	1.67 ± 0.24	0.000
FVC	Preoperative	3.0 ± 0.3	2.9 ± 0.28	0.09
	Postoperative	2.4 ± 0.2	1.75 ± 0.29	0.000
PaO_2 (mmHg)	Preoperative	91 ± 6	89 ± 7	0.057
	Postoperative	86 ± 7	81 ± 8	0.001
SaO_2 (%)	Preoperative	95.1 ± 2.6	94.9 ± 2.4	0.586
	Postoperative	94.7 ± 3.2	91.6 ± 2.9	9.545

Preoperative and postoperative pulmonary function changes: minimally invasive group vs. open group (Supplementary Table 3)

In both groups, postoperative values for the measured pulmonary function tests were lower than they were before the operations. However, the decrement in the open surgery group was significantly greater than that in the minimally invasive surgery group (P<0.05) (**Table 3**).

Discussion

Esophageal cancer is a common gastrointestinal malignancy, and surgery is still the main treatment method. Prior research [7, 8] has shown that elderly patients with esophageal cancer who underwent surgical treatment experienced a treatment efficacy superior to that of other treatment methods, and the postoperative five-year survival rate in this group was 37.8%. Therefore, surgery should be the first treatment choice for elderly patients with esophageal cancer whose preoperative evaluation suggests that they can tolerate surgery; age is not an absolute contraindication. However, for elderly patients with physical weakness and many preoperative complications, traditional open surgery tends to exacerbate pain and increase the incidence of postoperative pulmonary infections. In severe cases, open surgery may even trigger respiratory failure in this population [9, 10]. Therefore, relieving pain and reducing respiratory complications is an urgent problem requiring a solution. With the promotion and application of combined laparo-thoracoscopic minimally invasive surgery to treat esophageal cancer, the surgical treatment of esophageal cancer has made significant progress [11, 12]. Due to its advantages of low trauma, less intraoperative blood loss, mild pain, rapid postoperative recovery, and low impact on pulmonary function as well as its maintenance of thorax and abdomen integrity, combined laparo-thoracoscopic minimally invasive surgery has been gradually applied to elderly patients with esophageal cancer and has achieved good efficacy [13, 14].

Pulmonary complications are the major cause of perioperative death in patients with esophageal cancer [15]. Due to deterioration of vital organ function, cases of esophageal cancer among elderly patients are often complicated with respiratory or cardiovascular and cerebrovascular diseases, and these patients also have poor expectoration capability and reduced immunity. Therefore, elderly individuals have increased postoperative airway secretions, and increases in airway resistance, tracheal spasm, pulmonary infection, respiratory failure, and other complications are more common [9]. In particular, traditional thoracotomy causes a high amount of trauma, and lung tissue is inevitably squeezed during the operation in order to expose the operation field. The diaphragm, intercostal muscle and other respiratory muscles are cut off due to the surgical requirement, which these patients cannot tolerate. Therefore, postoperative respiratory dysfunction occurs frequently. In addition, elderly patients have physical weakness, poor tolerance, and slow energy metabolism, which tend to cause severe pulmonary complications and can even lead to respiratory failure and death [10]. In the present study, the incidence of postoperative pulmonary complications in the minimally invasive surgery group was significantly lower than that in the open surgery group, suggesting that for elderly patients with esophageal cancer, choosing laparo-thoracoscopic minimally invasive surgery can effectively reduce trauma and prevent postoperative pulmonary complications. Postoperative pain in patients with esophageal cancer is an important factor that affects postoperative respiratory function [16]. In the present study, pain on the third postoperative day for the minimally invasive surgery group was significantly milder than that experienced by the open surgery group, and the postoperative pulmonary function injury condition was also better in the minimally invasive group. This finding suggests that elderly patients with esophageal cancer are weak and have a poor tolerance to pain. In addition, the pain of the thoracic incision after thoracotomy suppresses the cough reflex, causing patients to be unable to effectively expectorate. This condition can very easily lead to postoperative pulmonary infection and a series of pulmonary complications. Moreover, postoperative analgesic treatment can also interfere with the physiological regulation of the prevention of atelectasis by respiration, causing the incidence of pulmonary complications to further increase. The present study confirms that for elderly patients, choosing minimally invasive esophageal cancer surgery, which imparts low trauma and less pain, has a significant effect on relieving pain and reducing postoperative respiratory dysfunction.

The present study showed that on the fifth postoperative day, the FEV1 and FVC values for the minimally invasive surgery group decreased 23% and 20%, respectively, compared with the preoperative values. However, for the open surgery group, the FEV1 and FVC values on the fifth postoperative day decreased 40% and 39%, respectively, compared with the preoperative values. Therefore, the degree of pulmonary function impairment in the minimally invasive surgery group was significantly lower than that in the open surgery group. In addition, the corresponding postoperative PaO_2 and SaO_2 conditions of the minimally invasive group were significantly superior to those of the open surgery group. By around the 10th postoperative day, pulmonary function of both treatment groups had gradually recovered, and the differences between the two groups were significantly reduced. These results showed that among elderly patients with esophageal cancer, choosing minimally invasive surgery could significantly protect pulmonary function during the early postoperative stage. The minimally invasive surgery group had a significant advantage of less pulmonary function impairment compared with the open surgery group and correspondingly had a reduced incidence of postoperative pulmonary complications.

Studies have shown that the application of a CO_2 pneumoperitoneum during total endoscopic radical esophagectomy could affect postoperative respiratory function [17]. However, in the present study, we showed that postoperative respiratory function impairment and pulmonary complications within the minimally invasive surgery group were both superior to those of the open surgery group, suggesting that the application of a CO_2 pneumoperitoneum did not significantly impact patients in the minimally invasive surgery group. This is likely because traditional open surgery needs to cut open the abdominal wall and therefore leads to greater injury. Open surgery patients suffer a greater degree and longer duration of postoperative pain, and the recovery of abdominal breathing is slower, which affects the postoperative expectoration capabilities of patients. Therefore, open surgery affects patients' forced respiration, causing a reduction of exhaled air and a significant increase of residual air [18]. Because endoscopic esophageal cancer surgery imparts relatively less trauma, the incidence of postoperative complications within the minimally invasive group was lower.

Multiple factors cause postoperative complications. In particular, factors such as preoperative respiratory tract diseases, age, and the smoking index of elderly patients with esophageal cancer, as well as the preoperative and postoperative care received, are all associated with the incidence of postoperative pulmonary complications [19]. For elderly patients, early postoperative respiratory tract management and anti-infection treatments are particularly important for reducing the incidence of pulmonary complications, especially for patients with preoperative pulmonary diseases and a long smoking history. Because patients in this cohort were of advanced age, they returned to the intensive care unit (ICU) with tracheal intubation after the operation, and they were placed on a ventilator to assist with breathing. After the patients were awake and vital signs were stable, airway secretions were removed by suction, and the tracheal intubation was unplugged. Elderly patients have physical weakness and poor tolerance, and postoperative pain and fear tend to induce arrhythmia. Therefore, sufficient postoperative analgesia and sedation are needed as preventative measures [20]. To prevent postoperative pneumonia, routine cough and phlegm drugs and aerosol inhalation therapy need to be administered. To minimize pleural effusions, closed-chest drainage should actively be performed to allow the lungs to fully resuscitate. Most elderly patients with esophageal cancer have malnutrition and weight loss; therefore, early postoperative enteral nutrition support is extremely important for postoperative physical recovery and the prevention of complications [21]. Patients in the current cohort were routinely fed a nutrition solution through nasogastric tubes starting on the second postoperative day until the patients were able to eat by mouth. Energy and liquids were supplemented through the veins. Most patients had a good tolerance, and their recovery results were significantly better than that of patients receiving parenteral nutrition alone.

Conclusions

Combined laparo-thoracoscopic minimally invasive esophageal cancer surgery is superior to traditional open esophageal cancer surgery in reducing postoperative pulmonary infections in elderly patients with esophageal cancer. First, the magnification effect of the endoscope used in the combined laparo-thoracoscopic surgery allows the surgeon to observe the operation field more clearly and accurately, which is conducive to protecting adjacent tissues, reducing collateral injury, decreasing blood loss, and shortening operation time. Second, minimally invasive surgery effectively avoids injury to the chest wall, abdominal wall and diaphragm, maintains the integrity of the chest and abdomen, and minimizes injury to respiratory muscles. Therefore, the associated postoperative pain is relatively mild. In short, minimally invasive surgery can effectively protect the pulmonary function of elderly patients with esophageal cancer, reduce the incidence of postoperative pulmonary complications, and improve the efficacy of esophageal cancer surgery.

Disclosure of conflict of interest

None.

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Supplementary Table 1. General patient characteristics

Operation method	Gender	Age	Tumor location	TNM	Hypertension	Diabetes	Smoking	Operation method	Gender	Age	Tumor location	TNM	Hypertension	Diabetes	Smoking
L	M	74	L	III	1		1	O	F	66	M	III	1	1	
	M	69	M	II		1	1		M	67	M	II			1
	M	68	M	II	1	1	1		M	69	L	III		1	
	M	72	L	III					F	68	L	II			
	M	63	M	II			1		M	68	M	I	1		1
	M	64	M	II	1		1		M	70	M	III			
	M	72	L	I			1		M	72	M	II			1
	M	71	M	III		1			M	67	M	III			1
	M	64	U	I			1		M	69	M	III		1	
	M	65	M	II			1		M	65	U	III		1	1
	M	74	L	III			1		F	60	M	III			
	M	60	M	II			1		F	62	L	II			
	M	69	M	II	1				M	64	M	II			
	M	64	U	II			1		M	70	L	III			1
	F	69	M	I					M	68	M	I	1	1	1
	M	71	M	II			1		M	64	M	II			
	M	60	M	III	1	1	1		M	60	M	III	1		1
	F	64	M	II	1				M	71	M	I			1
	M	65	M	I			1		M	70	U	I			1
	M	67	M	II	1		1		M	66	L	II			1
	M	71	L	II			1		F	65	L	II	1		
	F	65	L	II					M	70	M	I			1
	F	66	M	II					M	66	M	II			1
	M	66	U	I			1		M	69	M	II	1		
	F	67	M	III		1			M	63	M	II			1
	M	67	M	III		1	1		M	69	M	II			1
	M	65	L	I			1		M	66	M	III	1		
	M	73	L	II			1		M	71	M	II			
	F	61	M	II					M	66	M	III			1
	M	62	U	II			1		M	64	U	I			1
	M	68	M	III		1	1		M	65	M	II	1		
	M	73	M	I					M	68	L	III			1
	F	67	M	II					M	64	M	I			1

M	66	M	I	1	1	M	63	M	IV	1	1
M	66	M	III	1	1	M	70	M	II		
M	71	M	II		1	M	67	L	III	1	
M	66	L	I		1	F	66	M	III		
M	63	M	I		1	M	64	M	II		1
F	60	M	III			M	66	M	IV	1	1
M	71	M	III		1	M	63	M	II		1

Supplementary Table 2. Intraoperation and postoperation complication

Operation method	FEV1		FVC		PaO_2		SaO_2		Operation method	FEV1		FVC		PaO_2		SaO_2	
L	pre	pos	pre	pos	pre	pos	pre	pos	O	pre	pos	pre	pos	pre	pos	pre	pos
	2.66	2.04	2.93	2.52	87	80	100	98		2.82	1.78	3.28	1.44	98	94	99	93
	3.13	2.43	2.99	2.66	95	85	99	97		2.74	2.09	2.57	2.16	85	73	94	90
	2.66	2.41	3.09	2.47	90	83	96	91		3.22	1.73	2.96	1.57	94	82	98	92
	3.42	2.21	3.01	2.27	97	95	98	92		2.90	1.77	2.71	1.20	94	87	94	92
	3.34	2.36	3.04	2.27	82	85	92	91		2.80	1.61	2.45	2.23	80	75	92	90
	2.51	2.09	3.49	2.58	92	90	93	94		2.76	1.52	3.03	1.38	93	90	97	94
	3.15	2.80	3.32	2.63	97	93	98	94		2.21	1.38	2.86	1.95	82	79	95	88
	2.83	2.62	2.51	2.15	89	88	96	97		2.38	1.58	2.54	1.75	85	78	96	89
	3.02	2.44	2.74	2.57	84	81	95	95		3.04	1.31	2.65	1.97	97	85	96	93
	2.54	1.77	2.93	2.14	85	79	96	92		2.24	1.95	2.68	1.90	81	78	93	89
	2.63	2.47	2.53	2.04	93	81	94	95		3.03	1.68	3.12	1.43	89	77	97	94
	3.14	1.76	3.31	2.23	98	95	91	91		2.33	1.31	2.73	1.40	82	78	97	94
	2.81	1.89	3.26	2.60	96	95	96	95		2.62	1.46	3.30	2.26	96	89	96	92
	2.44	1.94	3.05	2.50	82	82	96	96		2.67	1.45	3.29	1.51	93	88	94	93
	2.93	2.53	3.21	2.44	90	88	98	93		3.33	1.50	2.84	1.40	80	82	89	96
	2.60	2.37	3.02	2.43	90	82	92	97		2.65	1.48	2.62	1.86	82	82	97	94
	2.97	1.94	3.05	2.36	84	84	93	93		2.73	2.05	3.08	1.59	84	68	97	87
	2.89	2.20	2.96	2.30	87	79	95	98		2.70	1.57	2.73	2.06	92	88	93	96
	2.96	2.41	2.82	2.49	95	89	96	99		2.65	1.68	3.20	1.57	93	85	94	93
	2.95	1.92	3.20	2.19	94	90	93	92		2.67	1.50	2.70	1.15	91	91	93	90
	2.50	2.51	2.73	2.11	97	95	92	98		3.16	1.53	2.83	1.91	83	78	93	92
	2.34	1.60	2.88	2.47	91	87	92	92		2.30	1.33	3.07	2.00	87	75	94	95
	3.00	1.91	3.34	2.74	96	91	96	97		2.89	1.60	3.14	1.37	96	80	93	96
	2.96	1.71	3.13	2.55	86	77	95	91		2.75	1.66	3.23	1.94	85	80	98	91

3.23	2.49	2.90	2.34	94	79	90	99	2.76	1.48	2.77	1.71	93	80	93	94
2.77	2.51	3.04	2.47	99	95	93	98	2.90	2.00	3.13	1.23	93	73	91	91
2.81	1.80	3.14	2.20	89	82	97	97	2.70	2.03	3.20	2.03	98	97	96	95
3.04	2.39	2.56	2.27	94	86	93	95	2.71	1.99	2.89	2.14	80	80	93	93
2.60	2.08	2.37	2.52	88	85	96	97	2.50	1.79	2.97	1.81	82	74	94	88
3.01	1.89	3.32	2.55	98	97	94	95	3.18	1.59	2.39	1.61	90	76	97	87
2.73	1.66	3.14	2.37	88	69	96	87	2.97	2.02	2.99	1.48	90	83	93	92
2.97	2.51	3.18	2.36	94	84	99	96	2.46	1.42	3.13	1.61	89	86	90	90
2.94	2.71	2.39	2.33	85	72	95	92	2.89	2.10	3.17	1.95	92	79	97	88
3.11	2.14	3.17	2.48	89	88	92	95	2.82	1.66	3.01	1.77	85	68	92	83
2.55	1.62	3.27	2.15	97	88	96	90	2.78	1.70	2.69	1.56	97	87	96	94
3.11	2.10	3.17	2.55	92	89	97	96	3.28	1.50	3.26	2.22	98	88	98	91
3.17	2.30	3.16	2.09	90	87	96	97	2.91	1.85	2.90	1.96	85	77	98	92
3.28	2.17	2.87	2.44	90	80	100	89	2.67	1.99	2.87	2.29	81	64	94	89
2.80	2.15	3.13	2.64	93	89	96	93	2.76	1.59	2.86	1.91	83	72	97	86
2.73	2.22	3.30	2.45	89	83	94	91	2.96	1.49	2.81	1.78	97	83	97	91

Supplementary Table 3. Pulmonary function and blood gas

Operation method	Operation time (m)	Blood loss	LN dissection	Days of drainage	Days of hospital	Pain score	RLN injury	Anastomotic fistula	Pulmonary infection	Atelectasis	ARDS	Pulmonary embolism	Respiratory failure	Pleu effusion
L	246	190	14	7	11	1								
	254	197	16	7	10	1								
	309	217	15	3	11	2			1					
	268	188	16	3	6	1								
	274	179	12	6	13	2								
	306	144	8	7	11	2			1	1				1
	303	235	16	7	10	1								
	351	239	15	5	9	2								
	289	180	12	4	10	2								
	312	205	13	5	13	1			1					
	300	220	17	7	14	2		1		1	1			1
	225	230	12	4	11	1			1					
	320	207	16	5	9	1								
	306	249	14	8	6	1								
	280	173	19	5	7	1								

	326	209	17	6	13	1							
	284	136	19	2	9	2							
	275	157	15	4	8	2							
	264	220	12	5	10	2							
	327	206	14	6	11	1							
	298	213	14	7	9	1							
	246	210	14	5	12	1							
	287	181	15	4	10	1							
	260	209	12	4	8	2	1		1				
	358	170	14	5	10	1							
	355	215	11	3	10	1							
	314	211	17	3	8	2							
	257	194	10	5	8	2							
	288	232	17	3	12	1							
	298	193	19	5	12	2							
	328	229	18	5	15	1	1	1	1	1	1	1	1
	262	216	15	7	9	1							
	283	221	16	7	10	2							
	338	157	11	4	13	2							
	329	246	14	6	14	1		1		1	1		1
	374	237	17	3	11	1							
	279	186	14	5	13	2							
	273	211	17	6	13	2			1	1	1		1
	296	183	17	6	9	1							
	252	276	14	6	14	1		1		1	1		1
0	337	490	20	5	13	2							
	353	491	11	8	10	2			1				
	338	540	14	8	14	3							
	344	474	15	7	11	3							
	350	599	11	5	15	4			1	1	1		1
	382	466	14	6	14	2							
	303	458	17	4	10	3			1				1
	337	426	15	6	15	2			1	1	1		1
	285	463	10	10	15	4							
	359	518	19	7	13	3			1		1		1
	339	456	13	10	11	2							

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358	478	13	6	9	2								
353	457	13	6	9	2								
396	462	15	5	18	3		1		1	1			1
376	544	19	7	11	2								
358	472	10	4	14	2								
349	511	14	6	12	3			1		1			1
326	450	11	6	10	3								
357	499	17	12	11	1								
313	513	20	2	11	3			1					
331	513	14	6	10	3								
333	480	16	7	12	4								
310	460	13	8	18	3		1		1				
300	460	11	5	16	2								
351	488	15	4	12	2								
375	495	19	7	15	3				1				
365	449	10	3	11	3								
364	485	18	5	12	2								
325	483	14	10	13	3			1					1
303	547	16	7	16	3		1	1	1	1			1
317	512	15	5	10	4	1							
328	522	13	6	14	2			1					1
325	499	15	6	12	2			1					
325	499	15	8	17	2			1	1	1	1	1	1
331	502	17	8	9	2								
373	481	9	6	16	3		1		1	1			1
344	474	19	7	12	4								
392	477	17	6	14	2			1					
319	479	15	5	17	1		1	1	1	1	1	1	1
326	520	19	12	13	3			1		1			1