Article

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Different Endotracheal Intubations for Non-Small Cell Lung Cancer Surgery: A Retrospective-Case-Matched Study on Postoperative Complications and Quality of Life

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Background: Lung isolation and separation is still controversial in thoracic surgery. Preferences of the surgeon can drive the decision to use single- vs. double-lumen endotracheal intubation. We aimed to compare complications and quality of life (QOL) after radical lung cancer resection with a single-lumen tube (ST) and a double-lumen tube (DT) for patients with non-small cell lung cancer (NSCLC).
Methods: A total of 309 patients who underwent radical lung cancer resection with video-assisted thoracoscopy-lobectomy were subsequently included in the study. Based on the type of endotracheal intubation tube used during surgery, we divided all the patients into a single-lumen tube group (ST-G) and double-lumen tube group (DT-G). Then, we applied propensity score matching (1:1) to balance the baseline characteristics between the two groups. The Analysis of Variance (ANOVA) of two-factor repeated measures data was performed to compare postoperative complications at three and six months after surgery and postsurgical QOL at baseline at one month, three months, six months, and twelve months.
Results: Within three months after surgery, patients in the ST-G presented less cough symptoms in Lung Cancer Symptom Scale (LCSS), lower cough symptom scores (CSS) (one month and three months, $p < 0.05$) and better performance of Leicester Cough Questionnaire (LCQ) scores in physical part (one month, three months and six months, $p < 0.05$) with better overall QOL (one month and three months, $p < 0.05$) than those in the DT-G.
Conclusions: Patients with STs displayed less postoperative cough symptoms and higher overall QOL than those with DTs. Although DT is the gold standard for thoracic surgeries, we suggest that postoperative cough symptoms should be given sufficient attention by surgeons.

Keywords: non-small cell lung cancer; endotracheal intubation; quality of life; cough after surgery; postoperative complications; video-assisted thoracoscopy-lobectomy

Introduction

Lung cancer is becoming the leading malignant cancer [1,2], and its incidence and mortality increase annually [3]. Surgery remains the cornerstone treatment for lung cancer [4,5]. Lung isolation is a fundamental anesthetic practice for surgeons to improve surgical conditions of the operative lung, which is accomplished either with a single-lumen tube (ST) or double-lumen tube (DT). Both techniques are essential to prevent lung secretions, blood, or necrotic tumor tissue from entering the contralateral lung, thereby reducing the likelihood of lung injury [6]. Currently, most clinicians consider DT to be the gold standard for thoracic surgery, as it is preferred for endotracheal intubations in many types of surgeries because of its quick inflation and ability to suck secretions during surgery [7].

However, tracheal intubation is often accompanied by common complaints such as cough and sore throat and often leads to long-term lung complications [8]. A persistent cough is a common postoperative complaint among patients after thoracic pulmonary resection as it may disturb sleep and influence speaking ability, which eventually worsens quality of life (QOL) [9]. Some learners have also highlighted the possibility of coughing causing airway injury in patients who were intubated with a DT [10]. The normal diameter of a DT is larger than that of an ST, so tracheobronchial contact is rougher, thereby increasing the possibility of cough stimulation [11,12]. Hence, clinicians should be aware of endotracheal intubation-related postoperative cough and its impact on QOL.

Many researchers have employed the Lung Cancer Symptom Scale (LCSS) in their prognosis-related research because of its reliability and feasibility concerning the assessment of overall QOL, symptomatic distress, and functional activity level [13,14]. The Leicester Cough Questionnaire (LCQ), visual analog scale (VAS) and cough symptom scores (CSS) have been routinely applied to evaluate the degree of patients' cough [15]. However, few studies have examined persistent postoperative airway irritation and postoperative complications following endotracheal intubation, especially after lung cancer surgery with video-assisted thoracoscopy-lobectomy.

Lung isolation and lung separation are common techniques that involve the use of bronchial barrier devices to disconnect the lungs, thereby enabling each lung to function separately. However, lung isolation is used to maximize surgical visualization during specific intrathoracic techniques and to support the management of certain pulmonary conditions [16]. The choice of using either double- vs. single-lumen, bronchial blocker-aided or endotracheal intubation depends on the practitioner's preference. Therefore, we conducted our research to determine whether there were differences in the incidence of postoperative complications between patients receiving these two types of tracheal intubation (ST and DT tracheal intubation) to provide an appropriate reference for lung cancer surgery.

The innovation of our study mainly shows the persistent status of complications and the precise analysis of cough status. For non-small cell lung cancer (NSCLC) patients who undergo video-assisted thoracoscopy-lobectomy, postoperative persistent cough symptoms can differ based on the type of endotracheal intubation tube that was used during surgery. The patients' quality of life in the double-lumen tube group (DT-G) is likely worse because of persistent cough. Thus, it may help clinicians obtain a more accurate prognosis for patients.

Methods

Patients

The calculation and justification of the sample size selected for this study: We retrospectively and continuously included three hundred and nine patients with NSCLC. All patients underwent radical lung cancer resection in our hospital from April 2020 to January 2021 (**Supplementary Table 1**). We recorded all intubation types during surgeries. Based on different endotracheal intubations, we divided all the patients into a single-lumen tube group (ST-G) and a double-lumen tube group (DT-G). A flow chart of our study is shown in Fig. 1. Our research followed the Declaration of Helsinki and was approved by the Ethics Committee of Tianjin Medical University Cancer Institute and Hospital, National Clinical Research Center for Cancer (Approval number: bc2021134), and informed consent was obtained from each patient.

Additional inclusion criteria were as follows: (i) American Association of Anesthesiologists (ASA) I–II grade, (ii) age (18–65 years), body mass index (BMI) (18.5–25 kg/m^2), (iii) no history of chronic cough-related diseases, asthma, severe cardiovascular disease, postnasal drip syndrome, acid reflux syndrome, and mental illness, (iv) surgery restraint to thoracoscopy-assisted lobectomy, and (v) single neoplasm restricted in one lobe without metastasis.

The exclusion criteria were as follows: (i) patients who were lost to follow-up or died, (ii) patients who were reluctant to complete the follow-up, and (iii) patients with teratomas, benign tumors, or pulmonary tuberculosis.

Anesthesia Method

After anesthesia, experienced anesthesiologists conducted endotracheal intubation with a fiberoptic bronchoscope (PENTAX FI-9BS, Tokyo, Japan).

In the single-lumen tube group (ST-G), the anesthesiologist pushed the tube into the main tracheal trunk with the assistance of fiberoptic bronchoscopy until it stabilized. Then, rotated a block device and stabilized it in the bronchus on the surgical side with the direct observation of fiberoptic bronchoscopy.

In the double-lumen tube group (DT-G), the anesthesiologist performed fiberoptic bronchoscopy to visualize the glottis. Turned it 90° counterclockwise for the left tube and 90° clockwise for the right tube. The tube core was removed when the bronchial capsule went through the coval fold, and then inflated a tracheal capsule after a safety check.

Baseline Data Enrollment

All clinical information was included from each patient: gender, age, height, weight, BMI, smoking history, Eastern Cooperative Oncology Group (ECOG) status, American Association of Anesthesiologists (ASA) classification, surgical treatment, surgical type, subcarinal lymph node dissection, surgical duration, anesthesia duration, tumor location, tumor area, pathological type (based on WHO (World Health Organization) classification [17]), and pathological TNM (Tumor Node Metastasis) stage (based on the latest standards of International Lung Cancer Research Association [18]). All data were collected from the Department of Lung Cancer Surgery workstation and anesthesia operating room in our hospital.

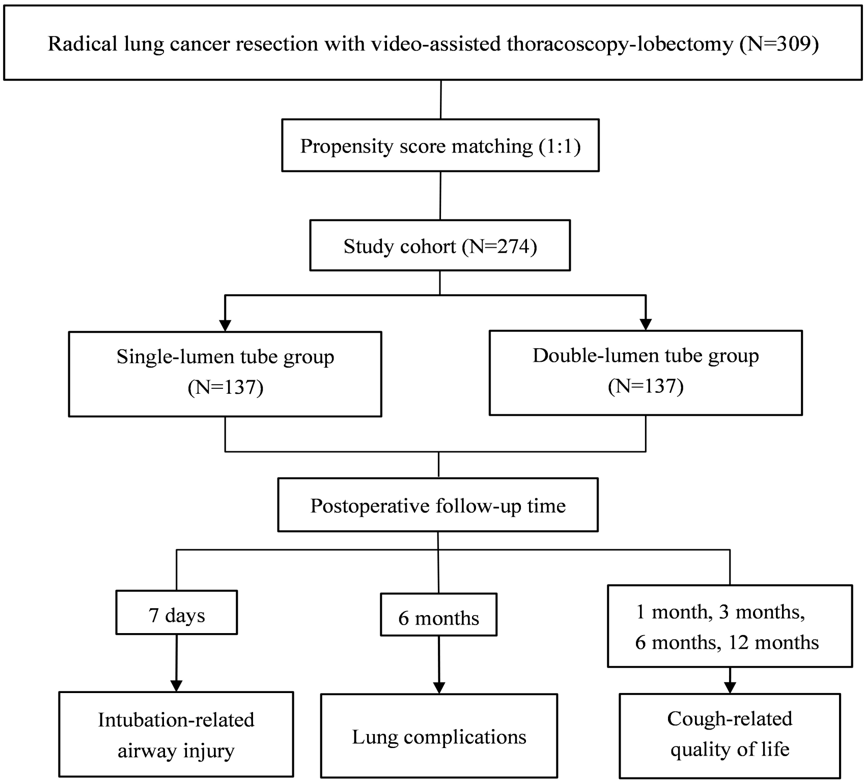

Fig. 1. Flow chart shows the outline of the study. The postoperative follow-up time was 7 days, 3 months, 6 months, and 12 months after each patient's surgery. This figure was drawn by Microsoft® Word 2021MSO (Version 2308 Build 16.0.16731.20182, Redmond, WA, USA).

Observation Indicators

The following intubation-related complications that occurred within seven days after surgery were monitored: sore throat, vocal cord paralysis, laryngeal edema, tooth pain, and mild hoarseness. Furthermore, severe lung complications were checked at three and six months after surgery, including atelectasis, acute respiratory distress syndrome (ARDS), lung infection, pleural effusion, wound infection, and chylothorax. The durations (days) of postoperative antibiotic application, thoracic drainage duration, and hospital stay were also observed. Moreover, the Lung Cancer Symptom Scale (LCSS) was used at baseline and one, three, six and twelve months after surgery.

We assessed QOL by the LCSS; each item was assessed with the VAS (a linear score of 0–10 points), while a lower value represents a better quality of life or less symptom burden [19]. Cough symptoms were assessed with cough symptom scores (CSS), including daytime and nighttime frequency which need to sum up to depict the cough frequency; the higher total scores always indicate more severe symptoms [20]. LCQ scores were used to accurately assess the status of postoperative cough from physiological, psychological, and social aspects [21].

Statistical Methods

We used 1:1 nearest-neighbor matching within a match tolerance value of 0.05 to conduct propensity score matching (PSM 1:1), aiming to reduce selective bias and the potential impact on clinical outcomes or QOL between the ST-G and DT-G. All the baseline characteristics mentioned above were analyzed by multiple logistic regression, presenting a matched cohort of 274 patients. Matched analysis was conducted to compare observation indicators. We firstly examined all the normal distribution between the two groups. Then, we conducted the ANOVA (Analysis of Variance) of two-factor repeated measures. After checking the compliance of the test results for sphericity, we analysed the intra- and inter-group relationship of these data. Then we compared the group*time and analysed the simple effect of time and group. Finally, we made the two-by-two comparisons analysis grouped by time in ST-G and DT-G.

We used SPSS (Version 26.0, Chicago, IL, USA) and GraphPad Prism (Version 9.4.1, San Diego, CA, USA) for data analysis. Chi-squared (χ^2) and Fisher's exact tests were applied to analyze categorical variables (presented as percentages). An independent *t* test was applied to assess continuous variables (presented as the mean $\pm$ standard deviation). The normality of distribution was examined. In all analyses, a *p* value of 5% or lower was regarded as significantly different.

Results

Baseline Characteristics before and after PSM

Three hundred and nine patients who were pathologically diagnosed with NSCLC were enrolled. Patients that underwent surgery for early-stage NSCLC were divided into the ST-G and DT-G groups based on the device used for intubation during anesthesia. All baseline data were normalized by PSM to reduce the potential for selection bias. Before PSM, differences in BMI ($p = 0.035$) and anesthesia duration ($p = 0.042$) were observed in the ST-G and DT-G. After 1:1 PSM, the characteristics of 274 patients were well-balanced (Table 1).

Comparison of Postoperative Complications between the ST-G and DT-G Groups

We analyzed the association between anesthesia intubation and consequent airway injury. We found that the incidence rate of a sore throat was lower in the ST-G group than in the DT-G group (ST 3.6% vs. DT 10.2%, $p = 0.032$). ST-G patients had lower incidence rates of vocal cord paralysis (ST 1.5% vs. DT 7.3%, $p = 0.018$), laryngeal edema (ST 0.7% vs. DT 3.6%, $p = 0.099$), tooth pain and loose (ST 0.7% vs. DT 2.9%, $p = 0.176$) and hoarseness (ST 11.7% vs. DT 19.7%, $p = 0.061$) than DT-G patients. Although the incidence rates of these items were lower in the ST-G group, only the sore throat and vocal cord paralysis were different between the two groups. However, there was no difference in the two groups including the items of atelectasis, ARDS, lung infection, pleural effusion, wound infection, and chylothorax (Table 2).

The durations of postoperative antibiotic application, thoracic drainage, and hospital stay did not significantly differ ($p > 0.05$), and the use of ST did not increase the total duration of such factors (**Supplementary Table 2**).

Comparison of Postoperative QOL between the ST-G and DT-G Groups

We performed LCSS, CSS and LCQ (Tables 3,4 and **Supplementary Table 3**) by conducting follow-ups at baseline, one, three, six, and twelve months after surgery to determine the postoperative QOL difference between the two groups. After confirming the normal distribution of the follow-up items, we applied the ANOVA of two-factor repeated measures data to confirm our conclusion (Tables 3,4). The S-W (Shapiro Wilke) test showed that the data of each group were normally distributed (**Supplementary Table 4**). In the sphericity test, all the repeated measured data did not meet the assumption of sphericity (**Supplementary Table 4**). Therefore, we used the correction results in the monadic ANOVA "Greenhouse-Geisser". The group effect, time effect and group*time effect in all the items showed a difference (Tables 3,4).

At baseline, the LCSS did not significantly differ between the ST-G and DT-G groups ($p > 0.05$). Subsequently, through the follow-up process, we found that most patients in the ST-G reported better overall QOL than those in the DT-G at one month (Mean, ST 5.8 vs. DT 6.6, $p < 0.05$) and three months (Mean, ST 3.9 vs. DT 4.3, $p < 0.05$) after surgery. During their recovery, most patients complained about the persisting cough. Notably, a significant difference was observed in the incidence of cough at one month (Mean, 4.3 vs. 4.8, $p < 0.05$) and three months (Mean, 1.5 vs. 2.1, $p < 0.05$), which was in accordance with the trend of QOL. These results are presented in Figs. 2,3.

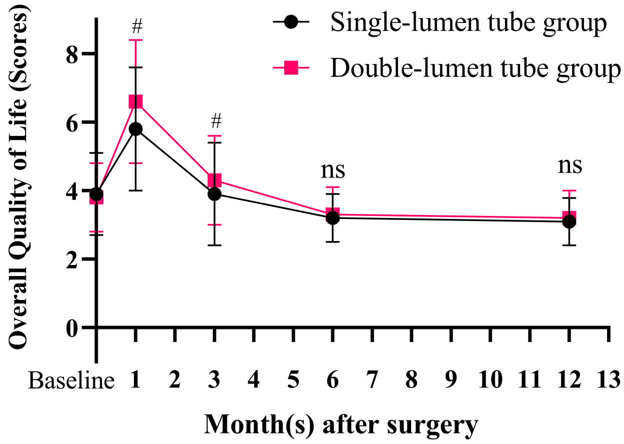

Fig. 2. Overall quality of life. At one month and three months after surgery, differences were observed. #, DT-G vs. ST-G, $p < 0.05$; ns, non-significant. Abbreviations: ST-G, single-lumen tube group; DT-G, double-lumen tube group.

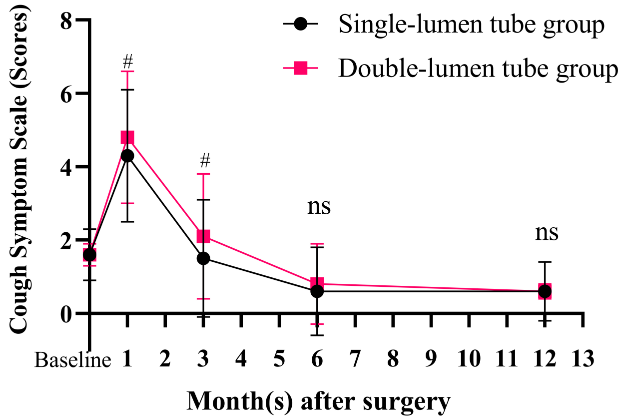

Fig. 3. Cough symptom scale. At one month and three months after surgery, significant differences were observed. #, DT-G vs. ST-G, $p < 0.05$; ns, non-significant.

Table 1. Baseline data of the unmatched and matched cohorts.

Characteristics		Unmatched Cohort (n = 309)		χ^2/T *values*	*p*	Matched Cohort (n = 274)		χ^2/T *values*	*p*
		ST-G (n = 151)	DT-G (n = 158)			ST-G (n = 137)	DT-G (n = 137)		
Gender	Male	69 (45.7%)	83 (52.5%)	1.444 (χ^2)	0.230	69 (50.4%)	67 (48.9%)	0.058 (χ^2)	0.809
	Female	82 (54.3%)	75 (47.5%)			68 (49.6%)	70 (51.1%)		
Age (years)		56.7 ± 10.9	56.9 ± 9.8	0.170 (T)	0.865	57.0 ± 10.8	56.7 ± 9.7	0.242 (T)	0.809
Height (cm)		165.9 ± 7.1	166.2 ± 7.7	0.356 (T)	0.722	166.3 ± 7.2	166.4 ± 7.8	0.110 (T)	0.912
Weight (kg)		65.8 ± 10.0	67.9 ± 10.3	1.817 (T)	0.070	66.8 ± 10.0	67.3 ± 10.5	0.404 (T)	0.687
BMI (kg/m^2)		23.9 ± 2.8	24.6 ± 3.0	2.118 (T)	0.035	24.1 ± 2.8	24.2 ± 2.9	0.290 (T)	0.772
Smoking history	No	90 (59.6%)	93 (58.9%)	0.018 (χ^2)	0.895	77 (56.2%)	84 (61.3%)	0.738 (χ^2)	0.390
	Yes	61 (40.4%)	65 (41.1%)			60 (43.8%)	53 (38.7%)		
ECOG	0	135 (89.4%)	134 (84.8%)	1.446 (χ^2)	0.229	123 (89.8%)	120 (87.6%)	0.327 (χ^2)	0.567
	1	16 (10.6%)	24 (15.2%)			14 (10.2%)	17 (12.4%)		
ASA classification	I	13 (8.6%)	18 (11.4%)	0.663 (χ^2)	0.416	13 (9.5%)	15 (10.9%)	0.159 (χ^2)	0.690
	II	138 (91.4%)	140 (88.6%)			124 (90.5%)	122 (89.1%)		
Subcarinal lymph node dissection	No	52 (34.4%)	50 (31.6%)	0.522	0.602	45 (32.8%)	42 (30.7%)	0.389 (χ^2)	0.697
	Yes	99 (65.6%)	108 (68.4%)			92 (67.2%)	95 (69.3%)		
Surgical duration (min)		107.2 ± 40.8	115.2 ± 46.5	1.605 (T)	0.110	108.4 ± 40.7	111.3 ± 38.4	0.6066 (T)	0.5446
Anesthesia duration (min)		124.8 ± 42.3	135.3 ± 47.6	2.046 (T)	0.042	126.4 ± 41.9	129.6 ± 37.0	0.670 (T)	0.503
Tumor location	LU	27 (24.5%)	36 (22.8%)	3.456 (χ^2)	0.485	33 (24.1%)	30 (21.9%)	2.107 (χ^2)	0.716
	LL	21 (13.9%)	29 (18.4%)			19 (13.9%)	24 (17.5%)		
	RU	49 (32.5%)	55 (34.8%)			44 (32.1%)	48 (35.0%)		
	RM	15 (9.9%)	9 (5.7%)			13 (9.5%)	8 (5.8%)		
	RL	29 (19.2%)	29 (18.3%)			28 (20.4%)	27 (19.8%)		
Tumor area	Peripheral	147 (97.4%)	150 (94.9%)	1.206 (χ^2)	0.272	133 (97.1%)	131 (95.6%)	0.415 (χ^2)	0.519
	Central	4 (2.6%)	8 (5.1%)			4 (2.9%)	6 (4.4%)		
Pathological type	ADC	112 (74.1%)	110 (69.6%)	3.904 (χ^2)	0.142	104 (75.9%)	98 (71.5%)	1.779 (χ^2)	0.411
	SQ	6 (4.0%)	15 (9.5%)			6 (4.4%)	10 (7.3%)		
	Others	18 (21.9)	16 (20.9)			27 (19.7%)	29 (21.2%)		
pTNM stage	I	144 (95.4%)	146 (92.4%)	1.947 (χ^2)	0.378	129 (94.2%)	130 (94.9%)	0.604 (χ^2)	0.739
	II	5 (3.3%)	6 (3.8%)			6 (4.4%)	4 (2.9%)		
	III	2 (1.3%)	6 (3.8%)			2 (1.5%)	3 (2.2%)		

Note: Data shown as No. (%); (χ^2) means the χ^2 value for categorical variables, (T) means T value for continuous variables. Abbreviations: ST-G, single-lumen tube group; DT-G, double-lumen tube group; ECOG, Eastern Cooperative Oncology Group; ASA, American Association of Anesthesiologists; ADC, adenocarcinoma; SQ, squamous cell carcinoma; pTNM, pathological Tumor Node Metastasis; LU, left upper lobe; LL, left lower lobe; RU, right upper lobe; RM, right middle lobe; RL, right lower lobe; BMI, body mass index.

Table 2. Comparison of postoperative complications between the ST-G and DT-G groups.

Characteristics	Matched Cohort (n = 274)			
Within seven days after surgery	ST-G (n = 137)	DT-G (n = 137)	χ^2 values	*p bilateral*
Sore throat	5 (3.6%)	14 (10.2%)	4.581	0.032
Vocal cord paralysis	2 (1.5%)	10 (7.3%)	5.578	0.018
Laryngeal edema	1 (0.7%)	5 (3.6%)	2.726	0.099
Tooth pain and loose	1 (0.7%)	4 (2.9%)	1.833	0.176
Hoarseness	16 (11.7%)	27 (19.7%)	3.525	0.061
Within six months after surgery	ST-G (n = 137)	DT-G (n = 137)	χ^2 values	*p bilateral*
Atelectasis	12 (8.8%)	15 (10.9%)	0.370	0.543
ARDS	3 (2.2%)	2 (1.5%)	0.204	0.652
Lung infection	4 (2.9%)	1 (0.7)	1.833	0.176
Pleural effusion	57 (41.6%)	55 (40.1%)	0.060	0.806
Wound infection	4 (2.9%)	6 (4.4%)	0.415	0.519
Chylothorax	3 (2.2%)	1 (0.7%)	1.015	0.314

Note: Data shown as No. (%); (χ^2) means the χ^2 value for categorical variables. Abbreviations: ST-G, single-lumen tube group; DT-G, double-lumen tube group; ARDS, acute respiratory distress syndrome. Data are expressed as numbers (percentages). Within seven days after surgery, complications were diagnosed by the anesthesiologist; within six months after surgery, complications were diagnosed by oncologists and imaging specialists.

Further analysis was conducted to focus on cough symptoms, and we used the CSS, and LCQ to more accurately assess changes in cough status. In the ST-G and DT-G, cough symptom scores (CSS) were assessed at one month (Mean, ST 2.2 vs. DT 2.8, $p < 0.05$) and three months (Mean, ST 0.8 vs. DT 1.1, $p < 0.05$). LCQ scores in the physical part at one month (Mean, ST 5.5 vs. DT 4.9, $p < 0.05$), three months (Mean, ST 6.1 vs. DT 5.9, $p < 0.05$) and six months (Mean, ST 6.5 vs. DT 6.1, $p < 0.05$) were significantly different. One month after surgery, the frequency and intensity of cough increased in both groups. Significantly more cough symptoms occurred in the DT-G within the first three months after surgery. During the recovery period, the patients' cough symptoms continued to gradually alleviate, cough symptoms in both the ST-G and DT-G decreased and the differences also disappeared. Although more cough symptoms occurred in the DT-G, the patients' psychological and social statuses in the LCQ were similar to those in the ST-G. In other words, only persistent cough symptoms caused the significant differences, which further worsened QOL, and this phenomenon was more prominent in the DT-G group. These results are summarized in Table 4 .

For the other factors in LCSS including anorexia, fatigue, dyspnea, hemoptysis, pain, we still used the ANOVA for make the detail analysis. The time effect in all the items showed a significant difference ($p < 0.05$), but the group effect did not display a significant difference at each follow-up time. The different follow-up times in the ANOVA analysis showed that the symptoms increased from baseline to one month, and decreased from three months, six months and twelve months after surgery, and all reached significance ($p < 0.05$) (Tables 3,4).

Discussion

Our study demonstrated that within three months of radical lung cancer surgery, patients in the ST-G showed less severe cough symptoms and a better overall QOL than those in the DT-G before and after propensity score matching (Tables 3,4). Our research was restricted to lung cancer radical lobectomy, and the choice of endotracheal intubation method was important.

Our study found that ST caused less damage to the patient's vocal cord, which has been proven in many studies [22] . Ruetzler *et al*. [23] found that the incidence of voice alterations was lower in ST-G than in DT-G, and the incidence of vocal cord paralysis was also lower in ST in this study. Similarly, Jo Mourisse *et al*. [24] proved that the efficiency and effectiveness of STs cause less sore throat and hoarseness than DTs. Our findings are consistent with the view that ST causes a lower incidence of sore throat (ST 3.6% vs. DT 10.2%) and laryngeal edema (ST 0.7% vs. DT 3.6%). The overall incidence of complications was lower than that in many other studies, which might be explained by the fact that our study was limited to patients with early-stage NSCLC and that all basic statuses and ASA grades were relatively good.

In our study, we conducted the long term lung complications including atelectasis, ARDS, lung infection, pleural effusion, wound infection, and chylothorax between the two groups. But the incidence rate of each item showed no difference in ST-G and DT-G. During surgery time, the pressure of tracheal intubation can compress the capillaries of the tracheal mucosa alongside edema and necrosis in the local mucosa [25]. Therefore, it may cause secretions to pour into the uninvolved lung leading to postoperative

Table 3. The ANOVA of two-factor repeated measures data in LCSS items in Matched Cohort.

Characteristics	Matched Cohort (n = 274)		Time		Group		Time*Group	
	ST-G (n = 137)	DT-G (n = 137)	F	*p*	F	*p*	F	*p*
Cough			597.814	***	7.461	**	4.063	*
Baseline	1.6 ± 0.7	1.6 ± 0.3						
One (M)	4.3 ± 1.8[a]	4.8 ± 1.8[#a]						
Three (M)	1.5 ± 1.6[b]	2.1 ± 1.7[#ab]						
Six (M)	0.6 ± 1.2[abc]	0.8 ± 1.1[abc]						
Twelve (M)	0.6 ± 0.8[abc]	0.6 ± 0.2[abc]						
Overall QOL								
Baseline	3.9 ± 1.2	3.8 ± 1.0	303.534	***	9.617	**	5.688	**
One (M)	5.8 ± 1.8[a]	6.6 ± 1.8[#a]						
Three (M)	3.9 ± 1.5[b]	4.3 ± 1.3[#ab]						
Six (M)	3.2 ± 0.7[abc]	3.3 ± 0.8[abc]						
Twelve (M)	3.1 ± 0.7[abc]	3.2 ± 0.8[abcd]						
Anorexia			201.008	***	0.108	ns	1.394	ns
Baseline	2.7 ± 0.7	2.8 ± 0.6						
One (M)	3.1 ± 0.9[a]	3.2 ± 1.0[a]						
Three (M)	2.6 ± 0.8[b]	2.5 ± 0.8[ab]						
Six (M)	2.6 ± 0.7[b]	2.5 ± 0.5[ab]						
Twelve (M)	1.6 ± 0.8[abcd]	1.5 ± 0.5[abcd]						
Fatigue			1567.117	***	0.017	ns	1.019	ns
Baseline	2.2 ± 1.1	2.2 ± 0.9						
One (M)	7.5 ± 2.1[a]	7.4 ± 1.9[a]						
Three (M)	7.2 ± 0.8[a]	7.4 ± 0.9[a]						
Six (M)	4.4 ± 0.6[abc]	4.4 ± 0.6[abc]						
Twelve (M)	2.0 ± 0.8[bcd]	2.0 ± 0.6[bcd]						
Dyspnoea			6315.374	***	10.025	ns	1.328	ns
Baseline	1.3 ± 0.2	1.3 ± 0.4						
One (M)	6.6 ± 0.6[a]	6.4 ± 0.6[a]						
Three (M)	5.8 ± 0.3[ab]	5.8 ± 0.4[ab]						
Six (M)	4.0 ± 0.5[abc]	3.9 ± 0.4[abc]						
Twelve (M)	2.1 ± 0.5[abcd]	2.0 ± 0.5[abcd]						
Hemoptysis			743.505	***	0	ns	2.013	ns
Baseline	2.5 ± 0.7	2.6 ± 1.1						
One (M)	3.5 ± 0.7[a]	3.3 ± 0.6[a]						
Three (M)	2.4 ± 0.7[b]	2.4 ± 0.7[ab]						
Six (M)	1.4 ± 0.3[abc]	1.4 ± 0.2[abc]						
Twelve (M)	0.9 ± 0.3[abcd]	0.8 ± 0.4[abcd]						
Pain			0.489	***	3650.288	ns	0.597	ns
Baseline	1.5 ± 0.7	1.5 ± 0.2						
One (M)	7.9 ± 0.3[a]	7.9 ± 0.4[a]						
Three (M)	5.0 ± 0.7[ab]	4.9 ± 0.7[ab]						
Six (M)	2.7 ± 1.2[abc]	2.8 ± 1.2[abc]						
Twelve (M)	2.7 ± 0.8[abc]	2.8 ± 0.5[abc]						
Distress			2541.931	***	0.72	ns	1.637	ns
Baseline	6.7 ± 1.0	6.5 ± 1.1						
One (M)	6.7 ± 1.1	6.5 ± 1.2						
Three (M)	3.3 ± 0.6[ab]	3.3 ± 0.4[ab]						
Six (M)	2.5 ± 0.7[abc]	2.6 ± 0.4[abc]						
Twelve (M)	1.7 ± 0.7[abc]	1.7 ± 0.3[abc]						
Activity level			3038.453	***	0.316	ns	2.308	ns
Baseline	2.4 ± 0.7	2.4 ± 0.6						
One (M)	8.6 ± 0.2[a]	8.6 ± 0.2[a]						
Three (M)	5.6 ± 1.2[ab]	5.3 ± 1.2[ab]						
Six (M)	4.0 ± 0.8[abc]	4.0 ± 0.9[abc]						
Twelve (M)	2.1 ± 1.1[abcd]	2.2 ± 1.0[abcd]						

Note: Abbreviation used as follows: ANOVA, Analysis of Variance; LCSS, Lung Cancer Symptom Scale; (M), Month/Months after surgery; ST-G, single-lumen tube group; DT-G, double-lumen tube group. [#]: DT-G vs. ST-G, $p < 0.05$; a: Compared with Baseline, $p < 0.05$; b: Compared with One (M), $p < 0.05$; c: Compared with Three (M), $p < 0.05$; d: Compared with Six (M), $p < 0.05$; QOL, quality of life. The difference of Time, Group, Time*Group are distinguished as ***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$, ns: non-significant. Significant differences are distinguished as $p < 0.05$. One decimal place was reserved for the data, presented as the mean ± standard deviation.

Table 4. The ANOVA of two-factor repeated measures data in cough items in Matched Cohort.

Characteristics	Matched Cohort (n = 274)		Time		Group		Time*Group	
	ST-G (n = 137)	DT-G (n = 137)	F	*p*	F	*p*	F	*p*
CSS			597.814	***	7.461	**	4.063	*
One (M)	2.2 ± 0.6	$2.8 \pm 0.6^{\#}$						
Three (M)	0.8 ± 0.9^{a}	$1.1 \pm 1.0^{\#a}$						
Six (M)	0.6 ± 0.7^{ab}	0.6 ± 0.7^{ab}						
LCQ Physical part			572.399	***	83.077	***	12.568	***
One (M)	5.5 ± 0.5	$4.9 \pm 0.5^{\#}$						
Three (M)	6.1 ± 0.5^{a}	$5.9 \pm 0.6^{\#a}$						
Six (M)	6.5 ± 0.4^{ab}	$6.1 \pm 0.3^{\#ab}$						
LCQ Psychological part			775.274	***	11.945	***	10.597	***
One (M)	6.0 ± 0.4	$5.8 \pm 0.3^{\#}$						
Three (M)	6.6 ± 0.4^{a}	6.6 ± 0.4^{a}						
Six (M)	6.9 ± 0.3^{ab}	6.9 ± 0.3^{ab}						
LCQ Social part			2161	***	0.057	ns	2.094	ns
One (M)	5.6 ± 0.3	5.6 ± 0.4						
Three (M)	6.5 ± 0.3^{a}	6.4 ± 0.4^{a}						
Six (M)	6.7 ± 0.3^{ab}	6.7 ± 0.3^{ab}						

Note: Abbreviation used as follows: (M), Month/Months after surgery; ST-G, single-lumen tube group; DT-G, double-lumen tube group; CSS, cough symptom scores; LCQ, Leicester Cough Questionnaire. $^{\#}$: DT-G vs. ST-G, $p < 0.05$; a: Compared with One (M), $p < 0.05$; b: Compared with Three (M), $p < 0.05$. The difference of Time, Group, Time*Group are distinguished as ***: $p < 0.001$ **: $p < 0.01$, *: $p < 0.05$, ns: non-significant. Significant differences are distinguished as $p < 0.05$. One decimal place was reserved for the data, presented as the mean ± standard deviation.

complications [26]. However, some studies showed that an ST may cause the residual secretion which may lead to ARDS and lung infection [27,28]. The lack of significant differences in the period of postoperative antibiotic application, thoracic drainage, hospital stay, and lung complications may be possibly caused by incomplete lung isolation in the case of using ST ($p > 0.05$). There were a few patients in ST-G and DT-G suffered from these complications, we believed that it may due to the total time for the placement of the ST or DT is less than other studies.

The main characteristic for our study focused on the cough symptoms. By the follow-up, we found patients in DT-G that suffered more than ST-G. This begged the question: is ST better than DT? Replacing DT with ST was discussed in reported cases [29]. Issam Tanoubi's team [30] proved the feasibility of altering DT with ST to reduce cough immediately after thoracic surgery. However, few studies focused on the persistent cough symptoms during the postoperative period. We found that fewer cough symptoms occurred in ST-G during their convalescence. We agree that a thinner ST bifurcation-free structure can minimize irritation to the respiratory tract, which has been proven by comparable studies [31]. For example, the study by Ana Clayton-Smith *et al.* [32] described that different occurrences of airway injury may be attributed to different tube sizes. Normally, STs are thinner and can be more dexterous than DTs; hence, DTs are less likely to induce injury during intubation and extubation processes. During the intubation period, the higher DT pressure exacerbated the congestion and inflammation of the airway. All these problems may easily lead to stress and worsen tracheal injury [33]. When an anesthesiologist conducts the intubation process, he cannot avoid rotation of the catheter through the vocal and irritation to the mucosa of the trachea, bronchus, and vocal cords, which may accelerate the accumulation of bronchial secretions, triggering irritation of the airway and aggravating the continuous cough response after surgery [34,35].

For QOL analysis, we matched all clinical items that may contribute to QOL. Our study also showed that symptom scores were higher at one month than at baseline, and our authors reckoned that surgical trauma and developing symptoms caused lower QOL in both groups. Some researchers found that persistent cough could last for one year, and as time passed, cough symptoms were less common, and patients' LCSS scores decreased with higher self-reported quality of life. This finding aligned with the beliefs of many researchers that persistent cough is alleviated after lobectomy [36].

To eliminate the influence of the surgical type, all the cases we enrolled were restricted to single-port thoracoscopy-assisted lobectomy. In addition, we conducted PSM to balance the potential influential factors, including surgical side, tumor location, tumor pathological type and subcutaneous lymph node dissection. The outcomes of one-lung isolation devices are experience dependent, and significant differences were observed between expert and nonexpert thoracic anesthesiologists [37]. To reduce the potential for selection and indication biases, our operations were performed by the same team, and all tracheal intubations were performed by experienced anesthesiologists.

To obtain more accurate data and avoid the influence of missing follow-up information, we selected a recent continuous period to conduct our study. To keep the same treatment team and medical resources, we designed a single-center study. Although previous studies have always used the LSCC questionnaire for QOL because of its validity and convenience, other scales can be applied for validation in this study. The study has some limitations: firstly, this is a single-center retrospective study; secondly, our sample is relatively small. In the future, we aim to extend the follow-up time to evaluate imaging findings and further expand the sample size to verify our conclusions in a multicenter study.

Conclusions

During radical lung cancer resection with video-assisted thoracoscopy-lobectomy, single-lumen endotracheal intubation caused less damage to the airway than double-lumen endotracheal intubation in our study. Within three months after radical resection of NSCLC, patients with STs displayed fewer postoperative cough symptoms and better QOL than those with DTs. Although DT is the gold standard for thoracic surgeries, postoperative cough symptoms should be given sufficient attention by surgeons.

Availability of Data and Materials

The original data of our study can be acquired from contacting the corresponding author (Email: zhangzhenfa@tmu.edu.cn).

Author Contributions

MZ: Project administration, Formal analysis, Data curation, Investigation, Writing-review & editing, Visualization, Validation. ZX: Methodology, Software. CC: Conception and design, Resources, Writing-original draft. GW: Investigation. XW: Project administration, Visualization. YJ: Validation. YY: Conceptualization, Writing-review & editing. ZZ: Conceptualization, Writing-review & editing. All authors: Given final approval of the version to be published. All authors: Agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors: Drafting the manuscript, revising.

Ethics Approval and Consent to Participate

This research was approved by the Ethics Committee of Tianjin Medical University Cancer Institute and Hospital, National Clinical Research Center for Cancer (Approval number: bc2021134). Our study followed the Declaration of Helsinki. Informed consent was obtained from each patient.

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.24976/Discov.Med.202335179.92.

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