Original Article

Comparison of survival between lung cancer patients receiving single or multiple-incision thoracoscopic surgery

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Background: The effect of single-incision thoracoscopic surgery for lung cancer on long-term survival is unknown and no studies have investigated whether there are differences in survival between single and multiple incision approaches. We aimed to compare long-term overall survival and disease-free survival of patients who underwent single-incision thoracoscopic surgery with those who received multiple-incision thoracoscopic surgery for lung cancer.

Methods: We retrospectively analyzed 532 patients with lung cancer who underwent either single-incision (n=150) or multiple-incision thoracoscopic resection (n=382) during the period January 2000 to December 2014. Patients were matched on propensity score at a 1:2 ratio to estimate the effect of treatment on long-term and disease-free survival. Overall survival and disease-free survival were assessed using the Kaplan-Meier method, the log-rank test and Cox proportional-hazards regression.

Results: Propensity matching resulted in 138 patients in the single-incision group and 276 patients in the multiple-incision group. The matched patients in the single-incision group had a significantly better 5-year overall survival than those in the multiple-incision group (P=0.027). Disease-free survival was similar between the two groups before and after matching. The number of chest wall incisions did not influence overall survival or disease-free survival.

Conclusions: The long-term outcomes of single-incision thoracoscopic surgery are comparable to those of multiple-incision thoracoscopic surgery for lung cancer.

Keywords: Survival; single-incision; multiple-incision; thoracoscopic surgery; lung cancer

Submitted Sep 19, 2017. Accepted for publication Jan 09, 2018.
doi: 10.21037/jtd.2018.01.58
View this article at: http://dx.doi.org/10.21037/jtd.2018.01.58

Introduction

Lung cancer is the leading cause of cancer death worldwide (1,2). Although long-term survival remains poor for patients with metastatic disease, complete surgical resection is potentially curative for patients with early-stage lung cancer. Thoracoscopic surgery for lung cancer has been demonstrated to result in faster postoperative recovery and fewer postoperative complications than traditional open

surgery (3-7).

Although thoracoscopic surgery is recommended for the treatment of early-stage lung cancer, the surgical procedures such as the number of chest wall incisions have yet to be standardized. Theoretically, fewer chest wall incisions should result in less chest trauma, postoperative pain and inflammation. Previous case series have shown that thoracoscopic resection for lung cancer performed via a single incision is a safe and technically feasible procedure resulting in satisfactory short-term perioperative outcomes (8-15). Furthermore, other studies have shown that short-term outcome after resection via a single incision is similar to that after multiple-incision thoracoscopic surgery (16-20). However, to the best of our knowledge, no studies have investigated whether there are differences in long-term survival between the two thoracoscopic techniques. Therefore, we conducted a propensity-matched analysis to compare long-term overall survival and disease-free survival between patients with lung cancer who received single-incision thoracoscopic surgery and those who underwent resection via a multiple-incision approach.

Methods

This study was conducted at the Koo Foundation Sun Yat-Sen Cancer Center. Thoracoscopic anatomic resections have been performed at the center for the past 11 years, beginning with three-port thoracoscopy in 2005, a two-port technique in 2007 and a single-port approach in 2009. The protocols for performing single-incision and multiple-incision thoracoscopic lobectomy and segmentectomy used at the center are discussed in detail in our previous publications (10,11,16,17). This study was approved by the institutional review board of the Koo Foundation Sun Yat-Sen Cancer Center (KFSYSCC-IRB No. 20150623A).

In this study, we reviewed data on all patients who underwent lobectomy at our institution during the period 2000–2014. Surgical indications for lung cancer at our hospital include clinical T1–3 stage cancer with biopsy proven N0–1 disease or single-station N2 disease without evidence of distant metastasis as recommended by the National Comprehensive Cancer Network guidelines for non-small cell lung cancer (21). Lobectomy is the standard surgical resection for lung cancer although some selected patients with poor pulmonary function or other major comorbidities that contraindicate lobectomy are treated with sublobar resection. Intentional segmentectomy is always performed in patients with peripherally located cT1N0M0 lung cancers smaller than 2 cm in diameter.

We identified a total of 819 patients who received surgical resection for lung cancer during the study period. Exclusion criteria included: (I) multiple lung cancer (n=50); (II) adenocarcinoma in situ or stage IV disease (n=39); (III) scheduled thoracotomy (n=181); (IV) conversion to thoracotomy during thoracoscopic surgery (n=2); (V) thoracoscopic surgery via a subxiphoid incision (n=13); and (VI) in-hospital death within 30 days of surgery (n=2). A total of 532 patients fulfilled the inclusion criteria and were included for analysis. The patients were divided into a single-incision group and a multiple-incision group and propensity score matching was performed to eliminate differences in basic demographics between the two groups.

The clinical characteristics evaluated in this study included age, gender, comorbidity score, cell type, tumor size, pathologic stage, operative procedure, tumor location, operative time, intraoperative blood loss, retrieved numbers of lymph node, length of hospital stay, disease status and survival rate. Surgical mortality was defined as death within 30 days after the operation or during the same hospitalization. Comorbidity score was calculated based on the following comorbidities: chronic obstructive pulmonary disease, diabetes mellitus, tuberculosis or other cancer. A score of 0 indicated that the patient did not have any of those conditions; a score of 1 indicated that the patient had one of those conditions; and a score of 2 indicated that the patient had at least two of those conditions. Preoperative staging and radiologic work-up included history taking, physical examination, computed tomographic imaging of the chest and upper abdomen, and positron emission tomography-computed tomography. Tumors were staged according to the American Joint Committee on Cancer (AJCC) tumor-node-metastasis (TNM) staging system (AJCC staging manual, 7th edition).

Surgical technique

All surgeries were performed with double-lumen endotracheal tube intubation under general anesthesia. Patients were positioned in the decubitus position, and the surgeon stood at the anterior side of the patient. Thoracoscopic surgery was performed with three incisions, included 3- to 5-cm mini-thoracotomy at the anterior axillary line at the 4th or 5th intercostal space, a port at the 8th intercostal space in the mid-axillary line for thoracoscope and a 10-mm accessory incision at the tip of the scapula. The incision at the tip of the scapula

was omitted for 2-incision thoracoscopic surgery. With the growing endoscopic experience, the single incision (3- to 5-cm mini-thoracotomy) was made in the 6th intercostal space at the anterior axillary line. The Alexis® wound protector (XS size) was routinely used at the mini-thoracotomy wound for all patients. The surgical techniques of the single-incision approach are also similar to those of the multiple-incision method. Pulmonary vessels and bronchus were divided individually with endoscopic staplers under thoracoscopic guidance. Mediastinal lymphadenectomy facilitated with a Harmonic scalpel (Ethicon Endo-Surgery, Inc., Cincinnati, OH, USA) and several simple traction methods (10). A 10-mm, 30-degree thoracoscopic video camera was also routinely used.

Statistical analysis

Patients who received single-incision thoracoscopic surgery were matched on propensity score at a 1:2 ratio to those who received multiple-incision thoracoscopic pulmonary resection to minimize bias due to the nonrandom allocation of treatments among patients. Propensity scores were estimated using a logistic model that included gender, age, gender, cell type, tumor size, tumor location, pathological cancer stage, and operation types as covariates.

Demographic data and clinical information were compared before and after the matching between those who underwent single-incision thoracoscopic surgery and those who received multiple-incision thoracoscopic surgery for lung cancer. The independent *t*-test was used to compare differences in continuous variables and the chi-square test was used for the comparison of categorical variables. Overall survival was calculated based on the time period starting on the date of surgery for lung cancer and ending with death or on April 2016. Disease-free survival was defined as the interval between the date of surgery and the date of recurrence or the last follow-up on April 2016. Kaplan-Meier survival analysis was used to compare overall survival and disease-free survival between the un-matched and matched groups. Differences in survival were determined by the log-rank test. Univariate and multivariate Cox proportional hazards regression analyses were conducted before propensity score matching. Age, gender, comorbidity score, pathologic T stage, pathologic N stage, tumor location, operation type, cell type and number of incisions were included into a multivariate regression model to investigate the impact of surgical technique on overall survival and disease-free survival. A P value <0.05 was considered to indicate statistical significance. All statistical analyses were performed with the statistical package SAS for Windows (Version 9.2, SAS, Cary, NC, USA).

Results

A total of 532 patients who were treated via single-incision or multiple-incision thoracoscopic surgery were analyzed before propensity score matching. Of them, 150 (28.2%) received single-incision thoracoscopic surgery and 382 (61.8%) were treated with multiple-incision thoracoscopic surgery. The un-matched single-incision group comprised a higher proportion of females and younger patients and had a higher rate of segmentectomy than the multiple-incision thoracoscopic group. Propensity matching resulted in 138 patients in the single-incision group and 276 patients in the multiple-incision group. The clinical characteristics of the un-matched and matched patients are presented in *Table 1*.

The mean follow-up time was 29.35 months in the single-incision group and 81.30 months in the multiple-incision group. The outcome variables are summarized in *Table S1*. Analysis of the matched patients showed that that the single-incision group had a significantly shorter operative time, shorter length of hospital stay, a lower postoperative mortality rate and a lower rate of disease progression (defined by either death, local recurrence or metastasis) than the multiple-incision group.

The overall survival and disease-free survival rates for unmatched and matched patients are summarized in *Tables S2*,*S3*, respectively. The 1-, 3-, and 5-year overall survival rates for matched patients in the single-incision group were 97.8%, 88.5%, and 88.5%, respectively. For matched patients in the multiple-incision group the 1-, 3-, and 5-year overall survival rates were 97.5%, 87.3%, and 78.3%, respectively. Patients treated with single-incision thoracoscopic surgery had better 5-year overall survival than those treated with multiple-incision thoracoscopic surgery (P=0.027). However, disease-free survival was similar between the two groups before and after matching (*Table S3*).

The Kaplan-Meier curves for overall survival among the 532 un-matched patients stratified by number of incisions and by pathologic stage are shown in *Figure 1A*. There were no significant differences in survival between the single-incision and multiple-incision groups (*Figure 1A*) and no significant survival differences between the two groups of patients stratified by disease stage I, II or III (*Figure 1B-D*). The Kaplan-Meier curves for disease-free survival among the unmatched patients stratified by number of incisions and

Table 1 Clinical characteristics of patients before and after propensity-score matching

Variables	All patients			Propensity-matched patients		
	Single incision (n=150)	Multiple incisions (n=382)	P	Single incision (n=138)	Multiple incision (n=276)	P
Age (year)	59.08±10.91	61.97±11.11	0.007	59.41±11.17	60.55±11.73	0.344
Female gender	103 (68.67)	219 (57.33)	0.016	93 (67.39)	170 (61.59)	0.248
Comorbidity score*			0.338			0.372
0	104 (69.33)	239 (62.57)		96 (69.57)	173 (62.68)	
1	38 (25.33)	117 (30.63)		35 (25.36)	84 (30.43)	
2 and more	8 (5.33)	26 (6.81)		7 (5.07)	19 (6.88)	
Cell type			0.885			0.785
Adenocarcinoma	124 (82.67)	321 (84.03)		113 (81.88)	231 (83.70)	
SqCC	11 (7.33)	28 (7.33)		11 (7.97)	17 (6.16)	
Others	15 (10.00)	33 (8.64)		14 (10.14)	28 (10.14)	
Tumor size (mm)	2.64±1.43	2.82±1.43	0.175	2.70±1.45	2.74±1.42	0.780
Pathologic stage			0.364			0.875
1	110 (73.33)	256 (67.02)		99 (71.74)	193 (69.93)	
2	18 (12.00)	55 (14.40)		17 (12.32)	39 (14.13)	
3	22 (14.67)	71 (18.59)		22 (15.94)	44 (15.94)	
T stage			0.775			0.769
1	76 (50.67)	188 (49.21)		68 (49.28)	142 (51.45)	
2	63 (42.00)	166 (43.46)		59 (42.75)	118 (42.75)	
3	7 (4.67)	22 (5.76)		7 (5.07)	12 (4.35)	
4	4 (2.67)	6 (1.57)		4 (2.90)	4 (1.45)	
N stage			0.586			0.992
0	117 (78.00)	277 (72.51)		106 (76.81)	210 (76.09)	
1	12 (8.00)	37 (9.69)		11 (7.97)	22 (7.97)	
2	21 (14.00)	65 (17.02)		21 (15.22)	42 (15.22)	
3	0 (0.00)	3 (0.79)		0 (0.00)	2 (0.72)	
Operative procedure			<0.001			0.067
Wedge resection	9 (6.00)	23 (6.02)		9 (6.52)	18 (6.52)	
Segmentectomy	44 (29.33)	39 (10.21)		32 (23.19)	39 (14.13)	
Lobectomy	97 (64.67)	318 (83.25)		97 (70.29)	219 (79.35)	
Pneumonectomy	0 (0.00)	2 (0.52)		0	0	
Tumor location			0.346			0.349
RUL	41 (27.33)	138 (36.13)		40 (28.99)	102 (36.96)	
RML	15 (10.00)	31 (8.12)		26 (18.84)	45 (16.30)	
RLL	29 (19.33)	68 (17.80)		15 (10.87)	20 (7.25)	
LUL	41 (27.33)	91 (23.82)		36 (26.09)	69 (25.00)	
LLL	24 (16.00)	50 (13.09)		21 (15.22)	36 (13.04)	
Others	0 (0.00)	4 (1.05)		0 (0.00)	4 (1.45)	

Data are presented as mean ± standard deviation or number (percentage). *, includes chronic obstructive pulmonary disease, diabetes mellitus, tuberculosis and other cancers; 0 if the patient does not have any of these conditions; 1 if the patient has one of these conditions; 2 if the patient has at least two of these conditions. SqCC, Squamous cell carcinoma; RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe.

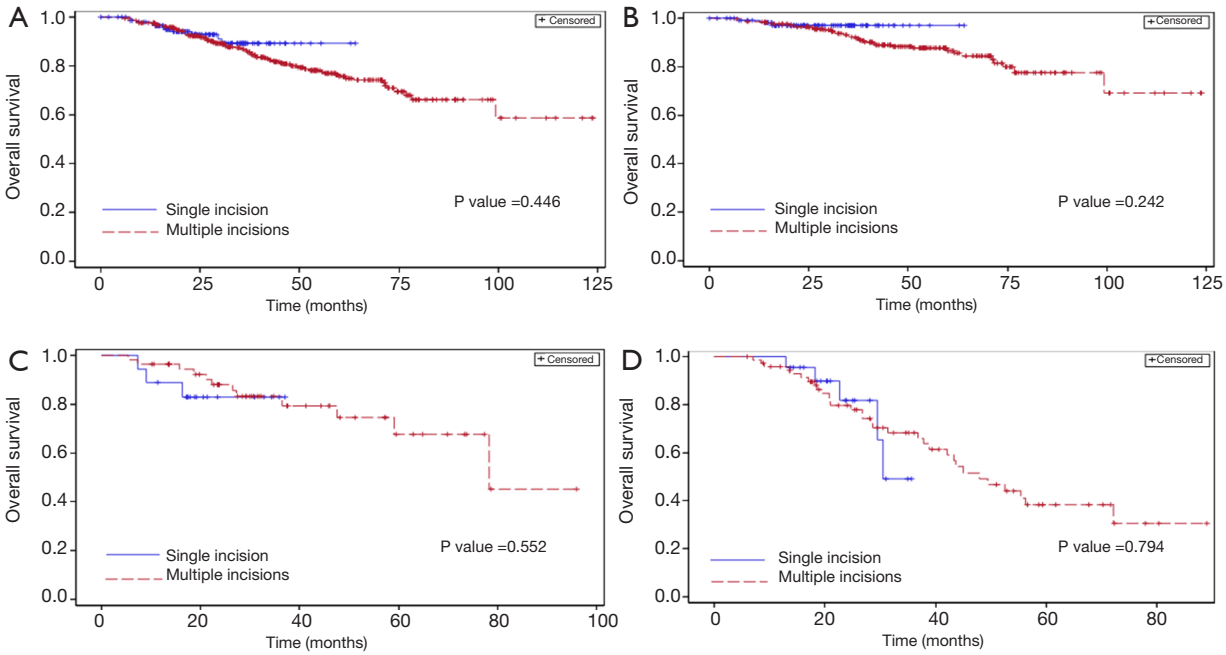

Figure 1 Kaplan-Meier overall survival curves stratified by incision numbers in (A) all 532 un-matched patients, (B) pathologic stage I un-matched patients, (C) pathologic stage II un-matched patients, (D) pathologic stage III un-matched patients.

by pathologic stage are shown in *Figure 2A-D*. Similarly, there were no significant differences in disease-free survival between the single-incision and multiple-incision groups (*Figure 2A*) and no significant survival differences between the two groups of patients stratified by disease stage (*Figure 2B-D*). Differences in overall survival between matched patients stratified by number of incisions and pathologic stage were also analyzed and the results are presented in *Figure 3A-D*. Kaplan-Meier analysis revealed that there was no significant difference in overall survival between the two groups (*Figure 3A*). In addition, there were no significant differences in overall survival between the two groups stratified by pathologic stage (*Figure 3B-D*). Disease-free survival was also similar between matched patients stratified by incision number (*Figure 4A*) and pathologic stage (*Figure 4B-D*).

Significant predictors of overall survival among un-matched patients in the univariate analysis (pathologic T stage, pathologic N stage, and cell type) were included in a multiple logistic-regression model to identify the most important predictors of overall survival. The results revealed that pathologic T stage, pneumonectomy and cell type were independent prognostic factors. The number of incisions, however, was not a significant predictor in either the univariate or multivariate analysis (*Table 2*). In the univariate analysis of disease-free survival in un-matched patients, pathologic T stage, pathologic N stage, and cell type were prognostic factors. In the multivariate analysis, however, only pathologic T stage and pathologic N stage remained predictors of disease-free survival. The number of incisions was not a significant predictor of disease-free survival in the univariate or multivariate analysis (*Table 3*).

Discussion

This study investigated the long-term overall survival and disease-free survival of patients with lung cancer who were treated with either single-incision or multiple-incision thoracoscopic resection. Propensity matching was conducted to create groups of patients who were well-matched with respect to age, sex, cell type, comorbidity score, tumor size, pathologic stage, operative procedure and tumor location. We found that overall survival and disease-free survival were similar between the two thoracoscopic techniques.

Gonzalez-Rivas and his colleagues reported that uniportal thoracoscopic lobectomy results in favorable perioperative outcomes (9). Similarly, we also previously reported that single-incision thoracoscopic lobectomy and

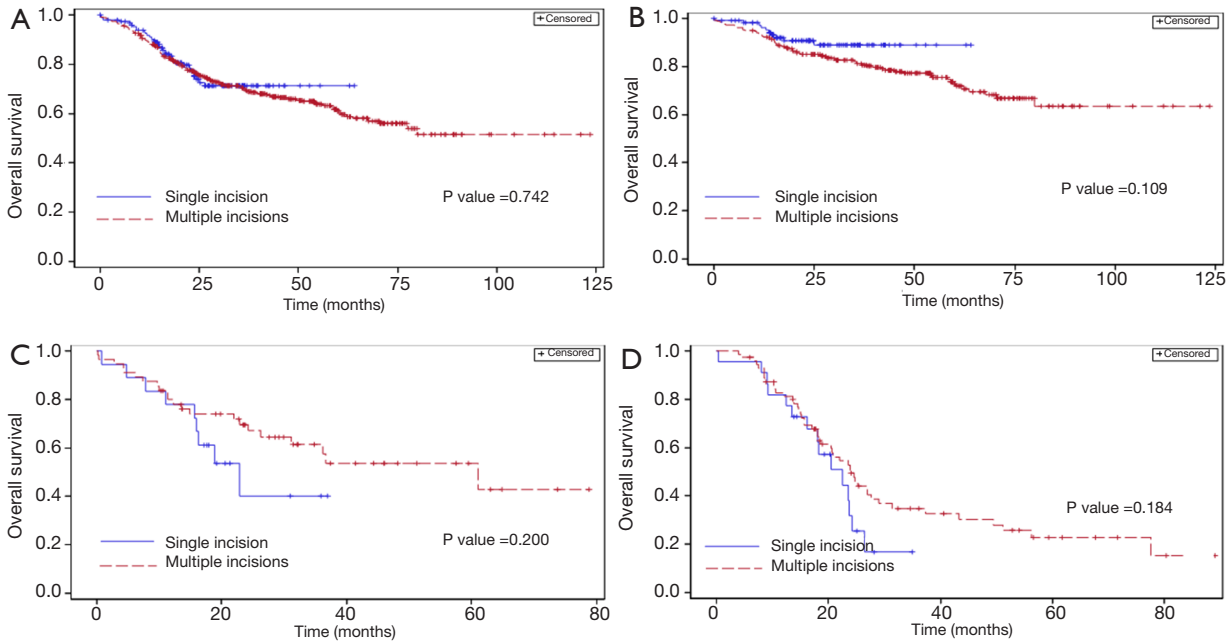

Figure 2 Kaplan-Meier disease-free survival curves stratified by incision numbers in (A) all 532 un-matched patients, (B) pathologic stage I un-matched patients, (C) pathologic stage II un-matched patients, (D) pathologic stage III un-matched patients.

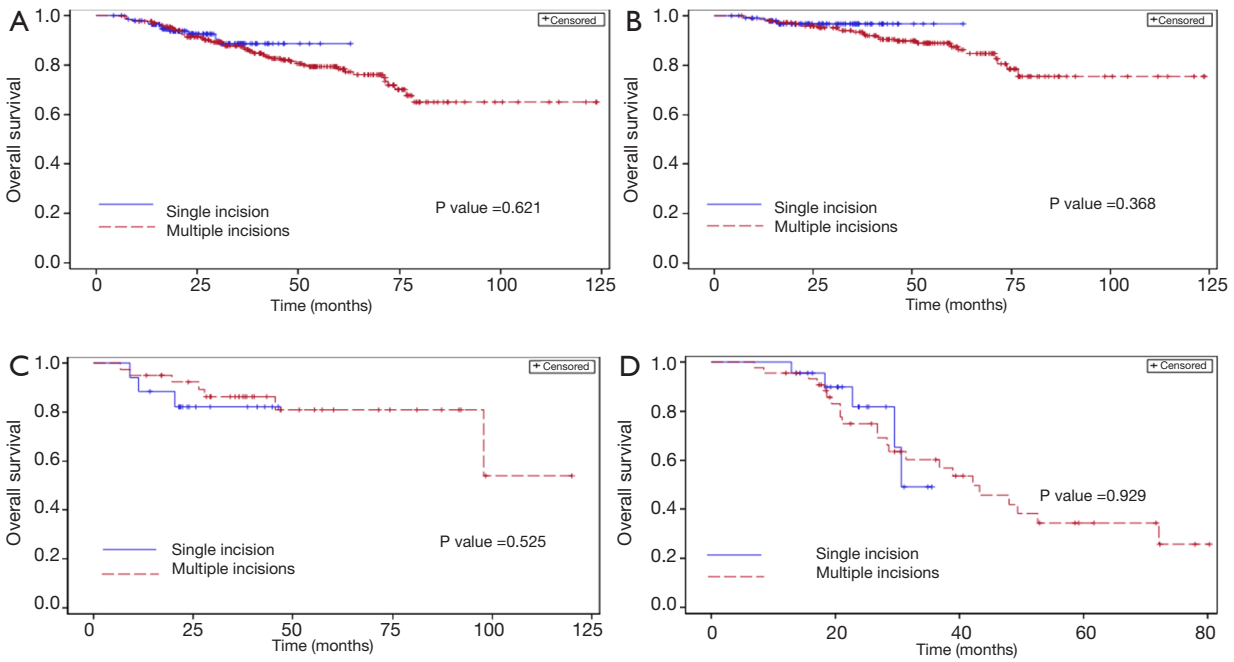

Figure 3 Kaplan-Meier overall survival curves stratified by incision numbers in (A) all 414 matched patients, (B) pathologic stage I matched patients, (C) pathologic stage II matched patients, (D) pathologic stage III matched patients.

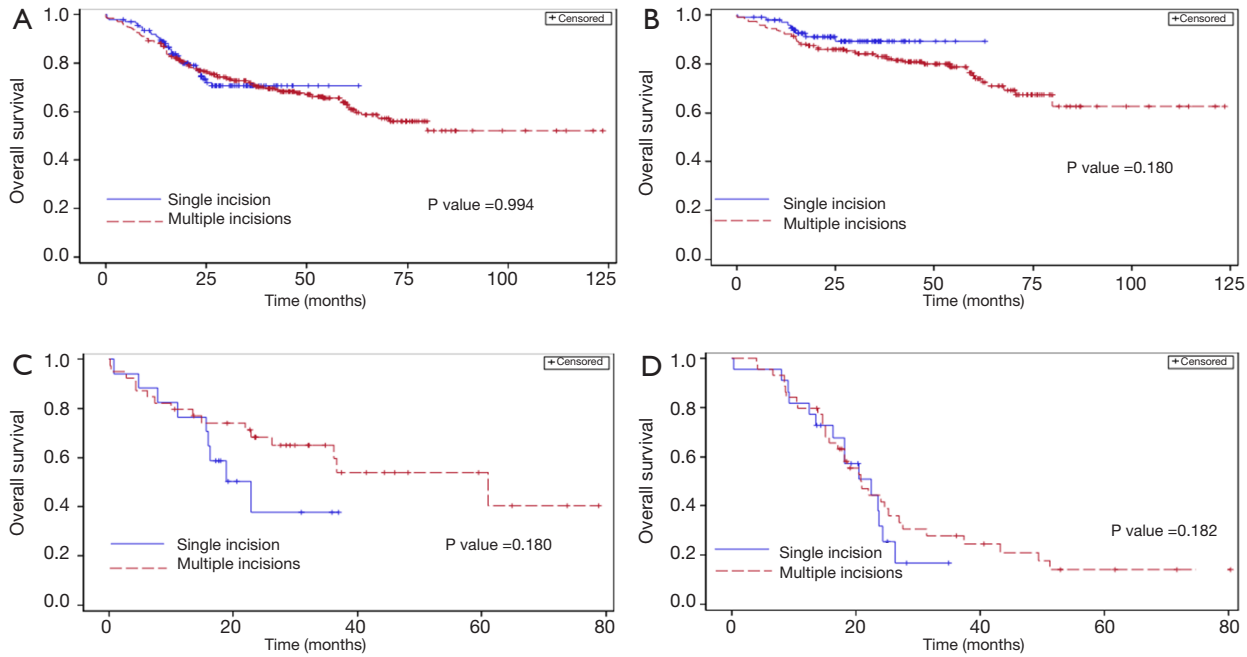

Figure 4 Kaplan-Meier disease-free survival curves stratified by incision numbers in (A) all 414 matched patients, (B) pathologic stage I matched patients, (C) pathologic stage II matched patients, (D) pathologic stage III matched patients.

segmentectomy good postoperative outcomes (10). In a large series (n=1,063) of patients who underwent single-incision thoracoscopic pulmonary resection Xie *et al.* and demonstrated that a single-incision approach results in less post-operative wound pain, faster recovery and better cosmetic results (13). Many thoracic surgeons across the world have adopted single-incision thoracoscopic surgery as the treatment of choice for patients with lung cancer (8-20).

Previous studies have demonstrated that overall survival after thoracoscopic surgery for lung cancer is equivalent to and in some cases better than that after thoracotomy (3). However, a few studies have reported on the short-term survival rates associated with single-incision thoracoscopic surgery for lung cancer. For example, Ng *et al.* (12) demonstrated that the overall 2-year disease-free survival rates among 150 consecutive patients who underwent single-port thoracoscopic resection for lung cancer were 96% for stage I disease and 83% for stage II or greater lung cancer. Also, Gonzalez-Rivas *et al.* (14) reported that the 30-month survival rate was 90% for early-stage lung cancer and 74% for advanced-stage lung cancer (>5 cm, or T3 or T4 or tumors requiring neoadjuvant chemotherapy). However, to the best of our knowledge, no studies have compared the long-term survival rates achieved with single-incision thoracoscopic surgery with those achieved with multiple-incision thoracoscopic surgery for lung cancer.

Therefore, we conducted a comparative study to investigate the influence of surgical incision numbers on long-term survival in patients with lung cancer. We found that patients in the single-incision group had better 5-year overall survival than those in the multiple-incision group before and after propensity score matching. Disease-free survival, however, was similar between the two groups before and after matching. The mortality rate was lower and the degree of disease progression was less severe in matched patients in the single-incision group than those in the multiple-incision group. This is a reasonable finding because the mean follow-up period in the single-incision group was markedly shorter (29.35 months) than that in the multiple-incision group (81.30 months) as we only began performing single-incision thoracoscopic surgery in 2009. The univariate and multivariate analyses showed that the number of chest wall incisions did not influence disease-free survival. We also found that long-term overall survival and disease-free survival were equivalent for both procedures when patients were stratified by pathologic stage. Our results, therefore, show that single-incision thoracoscopic surgery does not compromise long-term survival of patients with lung cancer.

A number of studies have directly compared short-term perioperative outcome between single-incision and

Table 2 Univariate analysis and multivariate analysis of overall survival in un-matched patients

Variables	Univariate			Multivariate		
	HR	95% CI	P value	HR	95% CI	P value
Age	1.006	0.988–1.025	0.5109	1.015	0.986–1.046	0.3197
Sex						
Female	1					
Male	1.495	0.985–2.269	0.0588	1.15	0.535–2.475	0.7202
Comorbidity score						
0	1			1		
1	1.185	0.747–1.881	0.4714	1.303	0.553–3.074	0.545
2	1.272	0.579–2.796	0.5493	2.14	0.53–8.636	0.285
T stage						
1	1			1		
2	2.668	1.653–4.306	<0.0001	2.05	1.094–3.84	0.025
3	5.371	2.411–11.964	<0.0001	0.796	0.142–4.479	0.796
4	18.122	8.084–40.624	<0.0001	6.362	1.66–24.373	0.007
N stage						
0	1			1		
1	2.785	1.466–5.293	0.0018	1.382	0.162–11.822	0.7677
2	4.95	3.128–7.836	<0.0001	1.293	0.099–16.823	0.8446
3	3.51	0.482–25.548	0.215	6.478	0.232–180.787	0.2713
Location						
RUL	1			1		
RML	1.179	0.693–2.006	0.5431	0.384	0.082–1.812	0.2268
RLL	1.073	0.577–1.997	0.8239	0.82	0.345–1.95	0.6539
LUL	0.501	0.176–1.422	0.1941	1.419	0.671–2.998	0.3597
LLL	1.187	0.629–2.24	0.596	0.743	0.278 -1.987	0.5539
Other	1.133	0.154–8.327	0.9021	–	–	–
Operation type						
Lobectomy	1					
Segmentectomy	0.913	0.484–1.724	0.7788	0.698	0.246–1.977	0.4986
Wedge	1.104	0.445–2.742	0.8307	0.998	0.256–3.898	0.9982
Pneumonectomy	4.759	0.658–34.403	0.1222	305.967	12.538–7,466.481	0.0004
Cell type						
Adenocarcinoma	1			1		
SqCC	3.912	2.136–7.164	<0.0001	4.861	1.649–14.327	0.0041
Others	1.61	0.801–3.236	0.1809	1.505	0.498–4.551	0.4689
Incision numbers						
Single incision	1			1		
Multiple incisions	1.287	0.671–2.468	0.4474	1.57	0.354–6.959	0.5527

CI, confidence interval; HR, hazard ratio; RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe; SqCC, Squamous cell carcinoma.

Table 3 Univariate analysis and multivariate analysis of disease-free survival in un-matched patients

Variables	Univariate			Multivariate		
	HR	95% CI	P value	HR	95% CI	P value
Age	1.005	0.991–1.019	0.5209	1.00	0.978–1.022	0.9985
Sex						
Female	1			1		
Male	1.279	0.942–1.737	0.1143	1.52	0.878–2.632	0.1351
Comorbidity score						
0	1			1		
1	1.125	0.800–1.581	0.4983	1.369	0.742–2.526	0.3150
2	1.585	0.922–2.725	0.0958	2.933	1.072–8.022	0.0361
T stage						
1	1			1		
2	2.951	2.096–4.155	<0.0001	3.301	2.041–5.34	<.0001
3	3.296	1.752–6.200	0.0002	2.539	0.836–7.705	0.1
4	10.468	4.892–22.400	<0.0001	9.252	2.486–34.433	0.0009
N stage						
0	1			1		
1	3.813	2.444–5.949	<0.0001	9.091	2.12–38.992	0.003
2	4.887	3.47–6.883	<0.0001	8.498	1.5–48.145	0.0156
3	35.957	11.005–117.481	<0.0001	52.9	3.304–847.003	0.005
Location						
RUL	1			1		
RML	1.184	0.795–1.764	0.405	0.626	0.242–1.624	0.3359
RLL	1.217	0.766–1.931	0.4058	0.674	0.365–1.244	0.2075
LUL	1.061	0.675–1.666	0.7975	1.111	0.637–1.936	0.7108
LLL	0.851	0.455–1.591	0.6126	0.652	0.315–1.346	0.2469
Other	0.631	0.087–4.569	0.6486	–	–	–
Operation type						
Lobectomy	1					
Segmentectomy	0.946	0.597–1.5	0.8145	1.627	0.727–3.642	0.237
Wedge	1.54	0.87–2.725	0.1383	2.099	0.769–5.728	0.1476
Pneumonectomy	2.32	0.325–16.567	0.4014	15.736	1.302–190.162	0.030
Cell type						
Adenocarcinoma	1			1		
SqCC	1.816	1.094–3.012	0.0209	1.011	0.396–2.581	0.9812
Others	0.927	0.525–1.638	0.7944	0.612	0.253–1.484	0.2774
Incision methods						
Single incision	1			1		
Multiple incisions	1.067	0.726–1.567	0.7423	1.001	0.451–2.219	0.9982

CI, confidence interval; HR, hazard ratio; RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe; SqCC, squamous cell carcinoma.

multiple-incision thoracoscopic surgery for lung cancer (16-20). In two of our previous studies we demonstrated that single-incision thoracoscopic surgery did not compromise perioperative safety of patients (16,17). Mu *et al.* compared uniportal and triportal thoracoscopic lobectomy and sublobectomy for lung cancer and found that short-term outcomes after uniportal thoracoscopic surgery were similar to those after triportal thoracoscopic pulmonary resection (18). Furthermore, Chung *et al.* (19) reported that the perioperative outcomes of uniportal thoracoscopic lobectomy were similar to those of multiportal thoracoscopy, indicating that uniportal thoracoscopic lobectomy is a viable alternative to performing the procedure via multiple incisions. Yan *et al.* (20) conducted a review article (n=1,314) and demonstrated the similar or better short-term outcome between single-incision and multiport thoracoscopic surgery in the treatment of lung cancer. In the current study, we found that patients in the single-incision thoracoscopic group had a shorter length of hospital stay and less blood loss than those in the multiple-incision group, indicating that single-incision thoracoscopic surgery results in similar if not better perioperative outcomes.

The primary limitations of this study are its retrospective design and selection bias, although we tried to reduce the degree of bias by matching patients on propensity score. We began thoracoscopic surgery for lung cancer with three-port in 2005, a two-port technique in 2007 and a single-port approach in 2009. We didn't perform different in the same period. We performed multiple-incision thoracoscope in the early period. Therefore, it contributed to uneven follow-up time between two groups. The mean follow-up differed markedly between the two groups because single-incision thoracoscopic surgery has been performed in our center for a shorter period of time than multiple-incision thoracoscopy. The difference in mean follow-up between the two groups, therefore, might have influenced the overall and disease-free survival results.

Conclusions

The long-term survival and disease-free survival rates achieved with single-incision thoracoscopic surgery are comparable to those achieved with multiple-incision thoracoscopic surgery for lung cancer.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: This study was approved by the institutional review board of the Koo Foundation Sun Yat-Sen Cancer Center (KFSYSCC-IRB No.: 20150623A).

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Cite this article as: Liu CC, Wang BY, Shih CS, Pennarun N, Lim LC, Gao SY, Cheng CT. Comparison of survival between lung cancer patients receiving single or multiple-incision thoracoscopic surgery. J Thorac Dis 2018;10(2):930-940. doi: 10.21037/jtd.2018.01.58

Supplementary

Table S1 Outcome variables of patients at baseline and after propensity-score matching

Variables	All patients			Propensity-matched patients		
	Single incision (n=150)	Multiple incisions (n=382)	P	Single incision (n=138)	Multiple incision (n=276)	P
Operative time (hours)	3.04 (0.92)	3.40 (1.07)	<0.001	3.05 (0.91)	3.40 (1.08)	0.001
Blood loss (Ml)	59.75 (78.91)	77.41 (91.70)	0.027	61.25 (81.69)	77.30 (96.86)	0.078
Number of lymph nodes	25.06 (12.49)	23.47 (11.85)	0.171	25.38 (12.74)	22.87 (11.97)	0.050
Length of stay (days)	5.87 (1.67)	6.69 (2.70)	<0.001	5.96 (1.64)	6.70 (2.88)	0.001
Vital status			<0.001			0.002
Alive	139 (92.67)	304 (79.58)		127 (92.03)	221 (80.07)	
Dead	11 (7.33)	78 (20.42)		11 (7.97)	55 (19.93)	
Progression*			0.007			0.029
No	116 (77.33)	249 (65.18)		105 (76.09)	181 (65.58)	
Yes	34 (22.67)	133 (34.82)		33 (23.91)	95 (34.42)	
Local recurrence			0.736			0.884
No	141 (94.00)	356 (93.19)		130 (94.20)	259 (93.84)	
Yes	9 (6.00)	26 (6.81)		8 (5.80)	17 (6.16)	
Metastasis			0.073			0.174
No	126 (84.00)	294 (76.96)		114 (82.61)	212 (76.81)	
Yes	24 (16.00)	88 (23.04)		24 (17.39)	64 (23.19)	

*, progression is defined by either death, local recurrence or metastasis.

Table S2 Overall survival rate of patients at baseline and after propensity-score matching

Timing	All patients					Propensity-matched patients				
	Single-incision (n=150)		Multiple-incision (n=382)		P	Single-incision (n=138)		Multiple-incision (n=276)		P
	Rate	95% CI	Rate	95% CI		Rate	95% CI	Rate	95% CI	
1-year	0.979	0.956–1.002	0.976	0.961–0.992	0.841	0.978	0.953–1.003	0.975	0.956–0.993	0.834
3-year	0.891	0.825–0.958	0.867	0.830–0.903	0.522	0.885	0.815–0.955	0.873	0.831–0.914	0.764
5-year	0.891	0.825–0.958	0.867	0.830–0.903	0.002	0.885	0.815–0.955	0.783	0.725–0.841	0.027

Table S3 Disease-free survival rate among patients at baseline and after propensity-score matching

Timing	All patients					Propensity-matched patients				
	Single-incision (n=150)		Multiple-incision (n=382)		P	Single-incision (n=138)		Multiple-incision (n=276)		P
	Rate	95% CI	Rate	95% CI		Rate	95% CI	Rate	95% CI	
1-year	0.917	0.872–0.962	0.895	0.864–0.926	0.430	0.919	0.873–0.965	0.891	0.855–0.928	0.358
3-year	0.712	0.627–0.798	0.703	0.655–0.751	0.841	0.705	0.617–0.793	0.719	0.664–0.774	0.795
5-year	0.712	0.627–0.798	0.611	0.553–0.669	0.054	0.705	0.617–0.793	0.628	0.561–0.694	0.171