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Original Article

Evaluation of the Factors Affecting Higher Hospitalization Cost of Lung Resection for Primary Lung Cancer: A Retrospective Cohort Study

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Purpose: This study aims to evaluate the factors associated with the higher hospitalization cost of lung resection for primary lung cancer to contribute to the reduction of healthcare spending.
Methods: A total of 435 consecutive primary lung cancer patients who underwent lung resection by a single surgeon at a single institution were enrolled. Baseline patient characteristics, operative procedures, postoperative complications, and postoperative courses were analyzed in relation to the hospitalization cost. Patients with higher costs (exceeding the third quartile [TQ]) were compared with patients with lower costs (less than TQ).
Results: Median and TQ medical costs for overall cases were 11177 US dollars (USD) and 12292 USD, respectively. Smoking history, history of coronary artery disease, previous thoracotomy, multiple sealant material use, transfusion, tumor factor T3 or higher, squamous cell carcinoma, postoperative complications, and longer postoperative hospital stay (>10 POD) were significant risk factors for increased hospitalization cost in multivariate analysis. The 5-year survival rate was significantly lower in the higher hospitalization cost group.
Conclusion: In addition to postoperative complications and prolonged hospitalization, patient background, histological types, and intraoperative factors were also considered as the risk factors for higher medical costs.

Keywords: primary lung cancer, hospitalization cost, lung resection

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Introduction

Increasing healthcare spending is a major social problem. In particular, medical expenses in our country are increasing by 70–100 billion dollars every 10 years, and the pace of increase exceeds the burden capacity of the country (i.e., economic growth). The ratio of national medical expense to gross domestic product is 7.81%, and the ratio to national income is 10.76% in 2016.[1)] On the other hand, while cancer has been the number one cause of death in Japan since 1960, lung cancer is currently the number one in terms of cancer deaths by site,[2)] and precise evaluation of its medical cost is considered essential. This study aims to evaluate the cost of lung resection for primary lung cancer by exploring the factors affecting higher hospitalization costs to suggest a path toward reducing healthcare costs.

Materials and Methods

A total of consecutive 435 primary lung cancer patients who underwent surgical resection at Gifu Prefectural General Medical Center by a single surgeon between 2011 and 2019 were enrolled, which included not only lobectomy cases but also sub-lobar resection cases (e.g., wedge resection, segmentectomy) and pneumonectomy cases.

The surgical procedure was performed under epidural and general anesthesia with dual-lumen endotracheal tubes. All procedures were performed under video assistance using a 10 mm, flexible thoracoscope with an anterolateral incision of 6–8 cm length through the 5th intercostal space. The vascular and bronchial structures were individually dissected and divided using Powered ECHELON FLEX 7 (or ENDOPATH ETS35 FLEX ATW35 before the launch of Powered ECHELON FLEX 7) for vessels and Powered ECHELON FLEX 60 stapler for fissures and bronchus (Ethicon, Cincinnati, OH, USA). Postoperative chest pain was controlled by multimodal analgesia, including the provision of epidural or continuous intravenous analgesia and/or nonsteroidal anti-inflammatory drugs, which were titrated to maintain adequate pain control to achieve early mobilization. Pathological tumor, node, metastasis (TNM) stages were described according to the 8th Edition of the International Association for the Study of Lung Cancer (IASLC) TNM classification. Histological types were described according to the histological classification at the time of operation. Hospitalization expenses mainly consisted of costs for surgery, anesthesia, medical materials (e.g., staplers, sealing materials), blood products, rehabilitation, and fees depending on the Diagnosis Procedure Combination (DPC) system of Japan. In Japan, medical fees and DPC coefficients are revised every two years and every year, respectively. In this study, hospitalization expenses were described according to the medical expenses billed at the time of discharge for each case. Based on the diagnostic group classification, the DPC system comprehensively calculates the cost of hospitalization, laboratory tests, drugs, injections, imaging studies, and so on. Representative medical costs in 2019 were as follows: surgery fee under video-assisted thoracic surgery (VATS) for wedge resection, 3788 US dollars (USD); segmentectomy, 4574 USD; lobectomy, 5793 USD; pneumonectomy, 5793 USD; general anesthesia with epidural anesthesia, 535 USD/3-hour; stapler, 157 USD/shot; fibrin sealant patch (TACHOSIL; Baxter Limited, Deerfield, IL, USA), 363 USD; fibrin glue (BOLHEAL; TEIJIN PHARMA Limited, Tokyo, Japan), 347 USD; polyglycolic acid (PGA) sheet (NEOVEIL; GUNZE Limited, Tokyo, Japan), 52 USD; patient-controlled analgesia pump, 5 USD/day; postoperative rehabilitation, 16 USD/day; red blood cells, 57 USD/unit; fresh frozen plasma, 61 USD/unit; platelet concentrate, 542 USD/10 units; and DPC charges for 1–5, 6–10, and 11–31 days, 182, 135, and 115 USD/day, respectively.

Since the hospitalization costs did not follow a normal distribution and could vary depending on the backgrounds between different countries, we divided the patients into two groups to determine the factors that increased these parameters: higher hospitalization cost group (HG; exceeding the third quartile [TQ]) and lower hospitalization cost group (LG; less than TQ). This ensured the external validity and interpretation of the current results. All costs are calculated at an exchange rate of 150 JPY per USD.

This was a retrospective study of prospectively collected data. The present study was conducted according to the principles outlined in the Declaration of Helsinki and the guidelines of the research ethics committee of Gifu Prefectural General Medical Center and approved by the institutional review board (GPGMC IRB-611).

Sub-analyses

As a sub-analysis, an evaluation of the factors for higher medical cost was also performed using the same approach limited to lobectomy cases, which is the standard procedure for lung cancer. Moreover, since the prolongation of postoperative hospital stay (PHS) was expected to contribute to the increase in medical costs under the DPC system due to the daily charge, additional investigation was performed by dividing lobectomy cases into long PHS and non-long PHS groups based on the TQ of PHS.

Statistical analysis

All data were analyzed using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria). Continuous variables are presented as the median and interquartile range and compared with the Mann–Whitney U test. Categorical variables were

Table 1 Baseline characteristics of all patients

Patient factors		Operation factors	
Age (years)	71 (65–76)	Operation time (min)	148 (118–184)
>80, n (%)	42 (9.6)	Stapler (shots)	5 (4–6)
Male, n (%)	287 (65.8)	Fibrin glue, n (%)	214 (49.1)
Smoking history, n (%)	292 (67.0)	PGA sheet, n (%)	204 (46.8)
Brinkman index > 400, n (%)	237 (81.1*)	Fibrin sealant patch, n (%)	201 (46.1)
Current smoker, n (%)	24 (5.5)	Blood loss (ml)	40 (12–130)
Comorbidities		Transfusion, n (%)	21 (4.8)
HT, n (%)	200 (45.9)	Postoperative factors	
HL, n (%)	106 (24.3)	Drain removal (POD)	3 (2–4)
DM, n (%)	80 (18.3)	>4 POD, n (%)	112 (25.7)
COPD, n (%)	65 (14.9)	Complications (any)	98 (22.5)
Asthma, n (%)	16 (3.7)	Postoperative hospital stay (days)	8 (7–11)
Interstitial pneumonia, n (%)	24 (5.5)	>10 POD, n (%)	99 (22.7)
CKD, n (%)	30 (6.9)	In-hospital mortality	3 (0.7)
HVD, n (%)	106 (24.3)	Re-admission	20 (4.6)
CAD, n (%)	54 (12.4)	Histological classification	
Atrial fibrillation, n (%)	23 (5.3)	Adenocarcinoma, n (%)	316 (72.5)
CVD, n (%)	39 (8.9)	BAC, n (%)	18 (4.1)
Gout, n (%)	25 (5.7)	Squamous cell carcinoma, n (%)	65 (14.9)
Liver disease, n (%)	19 (4.4)	Large cell carcinoma, n (%)	12 (2.8)
Previous malignancy, n (%)	127 (29.1)	Pleomorphic carcinoma, n (%)	7 (1.6)
Previous thoracotomy, n (%)	13 (3.0)	Carcinoid, n (%)	2 (0.5)
Neo-adjuvant therapy		Small cell carcinoma, n (%)	8 (1.8)
Chemotherapy, n (%)	10 (2.3)	Cost	
Radiation therapy, n (%)	8 (1.8)	Hospitalization cost (USD)	11177 (8548–12292)

*Percentage of patients with a smoking history.

HT: hypertension; HL: hyperlipidemia; DM: diabetes mellitus; COPD: chronic obstructive pulmonary disease; CKD: chronic kidney disease; HVD: heart valve disease; CAD: coronary artery disease; CVD: cerebrovascular disease; PGA sheet: polyglycolic acid sheet; BAC: bronchioloalveolar carcinoma; POD: postoperative day; USD: United States dollar

expressed as numbers and percentages and analyzed using the Fisher's exact test. Univariate and multivariate logistic regression analyses were performed for higher hospitalization costs. The multivariate analyses were performed with a backward step-wise deletion model in which each variable with a probability value of 0.1 or less in the univariate analysis was entered in the model. Actuarial survival and cancer-specific survival curves were estimated using the Kaplan–Meier method, comparing differences between groups with the log-rank test. Calculated P-values of less than 0.05 were considered significant.

Results

The overall baseline patient characteristics are shown in **Table 1**. Their median age was 71 years (65.8% male). Two hundred ninety-two patients (67.0%) had a history of smoking. Of those, 237 patients (81.1%) had a Brinkman index greater than 400. Regarding the details of the surgery, lobectomy, pneumonectomy, segmentectomy, and wedge resection were performed in 317 patients (72.9%), 10 patients (2.3%), 56 patients (12.9%), and 52 patients (12.0%), respectively. Concomitant lymph node resection was performed in 383 patients (87.8%). The median operation time was 148 min. Only 21 patients (4.8%) needed transfusion in the perioperative period. The occurrence of complications was described in 98 patients (22.5%) (prolonged air leakage: 27 patients, 6.2%; atrial fibrillation: 20 patients, 4.6%; pneumonia: 16 patients, 3.7%; pyothorax: 14 patients, 3.2%). Re-thoracotomy, adhesion therapy for prolonged air leakage, and newly home oxygen therapy induction were required in 9 patients (2.1%), 19 patients (4.4%), and 4 patients (0.9%), respectively. Three-quarters of patients were removed their chest drainage tubes within 4 days and were discharged within 10 days after the operation. Histopathologically, adenocarcinoma (316 patients, 72.5%) is overwhelmingly predominant, followed by squamous cell carcinoma (65 patients, 14.9%). The median and TQ hospitalization costs were 11177 USD and 12292 USD, respectively.

Table 2 shows the result of the analysis in relation to the hospitalization cost. One hundred nine patients were defined as the HG group whose hospitalization cost exceeded TQ hospitalization costs (18070 USD). Univariate analysis of baseline characteristics between the two groups revealed significant differences in gender, smoking history, chronic obstructive pulmonary disease (COPD), coronary artery disease, previous thoracotomy, neo-adjuvant chemo-/radio-therapy, 6-minute walk test, ppo% forced expiratory volume (FEV)1.0, and ppo% diffusing capacity for carbon monoxide (DLCO) between groups. As for operative factors, pneumonectomy, lobectomy, lymph node dissection, pulmonary artery plasty, fat pad use, chest wall resection, fibrin glue use, longer operation time, blood loss, and transfusion were frequent in HG. As for tumor factor, T3 or higher in TNM classification and histopathologically squamous cell carcinoma was higher in HG. Complications, such as prolonged air leakage, pneumonia, chylothorax, and pyothorax, were more frequent in HG. The costs of staplers, sealing materials, blood products and drugs, and rehabilitation fees were higher in HG. In multivariate analysis, smoking history (OR, 95% CI; 5.08, 2.63–9.81), coronary artery disease (CAD; 3.62, 1.48–8.89), previous thoracotomy (6.46, 1.63–25.60), multiple sealants use (9.05, 2.87–28.50), transfusion (16.3, 3.25–81.60), squamous cell carcinoma (3.66, 1.58–8.47), tumor factor T3 or higher (4.26, 1.70–10.60), postoperative complication (4.60, 2.78–7.66), and PHS >10 days (48.6, 23.70–99.60) were the isolated risk factors for increased hospitalization costs. On the other hand, wedge resection (0.47, 0.25–0.86) was the inverse factor for higher hospitalization costs. Both the 5-year overall- and cancer-specific survival rates of HG (62.9%, 78.2%) were significantly lower compared with LG (82.8%, 88.6%) (**Fig. 1A** and **1B**).

In the sub-analysis limited to the lobectomy cases (n = 317, **Supplementary Tables 1** and **2**), smoking history (7.68, 2.24–26.30); COPD (2.80, 1.25–6.26); interstitial pneumonia (7.12, 2.12–24.00); chronic kidney disease (CKD, 5.95, 1.43–24.70); CAD (5.16, 1.60–16.60), previous thoracotomy (12.20, 2.18–67.80), squamous cell carcinoma (3.59, 1.41–9.14) were the preoperative risk factors for higher medical costs in multivariate analysis. As for operative and postoperative factors, longer operation time (>3 hours, 4.32, 2.16–8.65), transfusion (32.80, 6.01–179.00), postoperative complication (4.55, 2.22–9.32), and longer PHS (>10 days, 77.30, 28.90–207.00) were the risk factors for higher medical costs. Regarding 5-year survival, overall survival was significantly lower in HG (64.6% vs. 81.9% in LG, **Fig. 2A**), but cancer-specific survival was not significantly different between the two groups (79.8% in HG, 87.3% in LG, **Fig. 2B**).

In the other sub-analysis divided by the third quartile of postoperative hospital stay (PHS) (**Supplementary Table 3**), the longer PHS group had significantly higher medical costs than the non-longer PHS group in all categories of medical costs, not just total medical costs. In multivariate analysis, tumor factor T3 or higher (2.89, 1.29–6.50), squamous cell carcinoma (3.17, 1.73–7.04), longer operation time (>3 hours, 2.97, 1.45–6.09), and postoperative complication (13.70, 6.61–28.3) were the significant risk factors for longer PHS.

Discussion

Increasing national medical care expenses is a major social problem in many countries. According to the Estimates of National Medical Care Expenditure of Japan, gross national medical expenses and medical expenses per capita are increasing every year. The ratio of national medical expense to national income has exceeded 10% since 2008.[1)] In contrast, lung cancer is currently the number one in terms of cancer deaths by site in Japan, as it does in the United States; there are few reports assessing the cost of surgical resection for lung cancer.[3,4)] Nakajima et al. compared the cost of VATS and open procedure for lung tumor over 20 years ago. However, it was considered challenging to reflect their report on the current situation because of bias in procedure selection (they basically performed VATS for high-risk cases), the inclusion of metastatic lung tumor cases (>20%), and relatively more extended hospital stay in both procedures (>2 weeks).[5)] In recent years, hospitalization cost comparisons between open, thoracoscopic, and robotic procedures have been reported; given that the majority of medical costs are operation-related costs, it was paradoxically meaningful to identify the factors that contribute to higher medical costs under a uniform strategy limited for primary lung cancer by a single surgeon at a single institution. In other words, we thought it would be possible to focus more on preoperative patient factors and postoperative complications relatively. Furthermore, we divided the patients into two groups to determine the factors that increased the hospitalization cost: higher

Table 2 Univariate and multivariate analyses of the risk factors for hospitalization cost exceeding the TQ (12292 USD)

	Univariate analysis			Multivariate analysis	
	HG	LG			
	(n = 109)	(n = 326)	P <0.05	OR (95% CI)	P
Patient factors					
Age	71 (66–76)	71 (64–76)			
>80, n (%)	13 (11.9)	29 (8.9)			
Sex Male, n (%)	93 (85.3)	194 (59.5)	*		
Smoking					
Smoking history, n (%)	97 (89.0)	195 (59.8)	*	5.08 (2.63–9.81)	<0.001
Brinkman index	880 (700–1200)	820 (500–1200)			
>400, n (%)	87 (79.8)	150 (46.0)	*		
Current smoker, n (%)	8 (7.3)	16 (4.9)			
Comorbidities					
HT, n (%)	54 (49.5)	146 (44.8)			
HL, n (%)	31 (28.4)	75 (23.0)			
DM, n (%)	25 (22.9)	55 (16.9)			
COPD, n (%)	32 (29.4)	33 (10.1)	*		
Asthma, n (%)	4 (3.7)	12 (3.7)			
Interstitial pneumonia, n (%)	12 (11.0)	12 (3.7)			
CKD, n (%)	12 (11.0)	18 (5.5)			
HVD, n (%)	23 (21.1)	83 (25.5)			
CAD, n (%)	23 (21.1)	31 (9.5)	*	3.62 (1.4–8.89)	0.005
Atrial fibrillation, n (%)	6 (5.5)	17 (5.2)			
CVD, n (%)	12 (11.0)	27 (8.3)			
Gout, n (%)	8 (7.3)	17 (5.2)			
Liver disease, n (%)	4 (3.7)	15 (4.6)			
Previous malignancy, n (%)	30 (27.5)	97 (29.8)			
Previous thoracotomy, n (%)	7 (6.4)	6 (1.8)	*	6.46 (1.63–25.60)	0.007
Neoadjuvant therapy					
Chemotherapy, n (%)	7 (6.4)	3 (0.9)	*		
Radiation therapy, n (%)	7 (6.4)	1 (0.3)	*		
Preoperative physical examinations					
6MWT (m)	490 (405–553)	530 (465–582)	*		
%VC (%)	106 (94–117)	109 (97–120)			
FEV1.0 (L)	2.2 (1.7–2.8)	2.2 (1.8–2.6)			
FEV1.0% (%)	71 (62–76)	74 (68–78)	*		
%FEV1.0 (%)	87 (74–99)	95 (83–107)	*		
ppoFEV1.0 (L)	1.6 (1.4–2.1)	1.8 (1.5–2.2)			
ppo%FEV1.0 (%)	68 (54–79)	78 (66–91)	*		
<40%, n(%)	5 (4.6)	7 (2.1)			
%DLCO (%)	87 (72–105)	101 (86–117)	*		
ppo%DLCO (%)	68 (55–83)	84 (70–98)	*		
<60%, n (%)	33 (30.3)	34 (10.4)	*		
Fibrosis markers					
KL-6 (U/ml)	304 (205–438)	232 (174–356)	*		
SP-D (ng/ml)	63.8 (36.4–118.9)	52.8 (29.6–84.5)			
SP-A (ng/ml)	41.8 (31.2–60.6)	34.3 (25.0–47.2)	*		
Operation factors					
Pneumonectomy, n (%)	5 (4.6)	5 (1.5)	*		
Lobectomy, n (%)	98 (89.9)	219 (67.2)	*		
Segmentectomy, n (%)	5 (4.6)	51 (15.6)	*		
Wedge resection, n (%)	1 (0.9)	51 (15.6)	*	0.47 (0.25–0.86)	0.015

(Continued)

Table 2 (Continued)

	Univariate analysis			Multivariate analysis	
	HG	LG			
	(n = 109)	(n = 326)	P <0.05	OR (95% CI)	P
Lymph node dissection, n (%)	108 (99.1)	275 (84.4)	*		
PA plasty, n (%)	11 (10.1)	4 (1.2)	*		
Bronchoplasty, n (%)	3 (2.8)	1 (0.3)			
Fat pad use, n (%)	8 (7.3)	5 (1.5)	*		
Chest wall resection, n (%)	9 (8.3)	2 (0.6)	*		
Aorta resection, n (%)	1 (0.9)	0			
Fibrin glue, n (%)	78 (71.6)	136 (41.7)	*		
PGA sheet, n (%)	72 (66.1)	132 (40.5)	*		
Fibrin sealant patch, n (%)	49 (45.0)	152 (46.6)			
Multiple sealants use (glue + patch), n (%)	22 (20.4)	8 (2.1)	*	9.05 (2.87–28.50)	<0.001
Operation time (min)	191 (148–270)	139 (110–166)	*		
>3 hours, n (%)	61 (56.0)	53 (16.3)	*		
Stapler (shots)	5 (4–7)	5 (4–6)	*		
Blood loss (ml)	150 (50–390)	28 (10–80)	*		
Transfusion, n (%)	18 (16.5)	3 (0.9)	*	16.3 (3.25–81.60)	<0.001
Postoperative factors					
Drain removal (POD)	4 (3–7)	2 (2–3)	*		
>4 POD, n (%)	56 (51.9)	56 (17.2)	*		
Post-op hospital stay (days)	12 (9–15)	7 (6–7)	*		
>10 POD, n (%)	81 (75.0)	20 (6.1)	*	48.6 (23.70–99.60)	<0.001
In-hospital mortality, n (%)	3 (2.8)	0	*		
Re-admission, n (%)	7 (6.4)	13 (4.0)			
Complications					
Overall complications, n (%)	50 (45.9)	48 (14.7)	*	4.60 (2.78–7.66)	<0.001
Atrial fibrillation, n (%)	9 (8.3)	11 (3.4)			
Pyothorax, n (%)	9 (8.3)	5 (1.5)	*		
Aggravation of IP, n (%)	4 (3.7)	1 (0.3)	*		
Pneumonia, n (%)	10 (9.2)	6 (1.8)	*		
Prolonged air leakage, n (%)	17 (15.6)	10 (3.1)	*		
Wound infection, n (%)	2 (1.8)	1 (0.3)			
Chylothorax, n (%)	3 (2.8)	0	*		
Bleeding, n (%)	2 (1.8)	2 (0.6)			
Additional therapy for complications					
Re-thoracotomy	7 (6.4)	2 (0.6)	*		
Adhesion therapy	12 (11.0)	7 (2.1)	*		
HOT introduction	2 (1.8)	2 (0.6)			
TNM classification					
Tis, n (%)	0	11 (3.4)			
T1, n (%)	24 (22.0)	169 (51.8)	*		
T2, n (%)	52 (47.7)	123 (37.7)			
T3, n (%)	19 (17.4)	20 (6.1)	*		
T4, n (%)	14 (12.8)	3 (0.9)	*		
Tis + T1 + T2, n (%)	76 (69.7)	303 (92.9)	*		
T3 + T4, n (%)	33 (30.3)	23 (6.1)	*	4.26 (1.70–10.60)	0.002
N1, n (%)	10 (9.2)	15 (4.6)			
N2, n (%)	7 (6.4)	13 (4.0)			
N3, n (%)	0	0			
M1, n (%)	0	1 (0.3)			

(Continued)

Table 2 (Continued)

	Univariate analysis			Multivariate analysis	
	HG	LG			
	(n = 109)	(n = 326)	P <0.05	OR (95% CI)	P
Histological classification					
Adenocarcinoma, n (%)	59 (54.1)	257 (79.6)	*		
BAC, n (%)	2 (1.8)	16 (5.0)			
Squamous cell carcinoma, n (%)	35 (32.1)	30 (9.3)	*	3.66 (1.58–8.47)	0.002
Large cell carcinoma, n (%)	6 (5.5)	6 (1.9)			
Pleomorphic carcinoma, n (%)	2 (1.8)	5 (1.5)			
Carcinoid, n (%)	0 (0)	2 (0.6)			
Small cell carcinoma, n (%)	2 (1.8)	6 (1.9)			
Adjuvant therapy					
Chemotherapy, n (%)	52 (47.7)	102 (31.3)	*		
Radiation therapy, n (%)	12 (11.0)	15 (4.6)	*		
Molecular targeted therapy, n (%)	9 (8.3)	18 (5.5)			
Cost					
Total cost (USD)	14078 (13450–15,742)	11715 (10904–12304)	*		
Procedure fee (USD)	8530 (8249–8851)	8097 (7126–8387)	*		
Drug cost (USD)	673 (616–1025)	598 (414–647)	*		
Stapler cost (USD)	1000 (667–1000)	883 (667–1000)	*		
Sealing material cost (USD)	535 (405–794)	405 (218–535)	*		
Rehabilitation fee (USD)	338 (237–487)	167 (131–211)	*		

*: P < 0.05.
All costs are calculated at an exchange rate of 150 JPY per USD.
TQ: third quartile; HT: hypertension; HL: hyperlipidemia; DM: diabetes mellitus; COPD: chronic obstructive pulmonary disease; CKD: chronic kidney disease; HVD: heart valve disease; CAD: coronary artery disease; CVD: cerebrovascular disease; 6MWT: 6-minute walk test; VC: vital capacity; FEV: forced expiratory volume; DLCO: diffusing capacity for carbon monoxide; ppoFEV1.0: predicted postoperative FEV1.0; ppoDLCO%: predicted postoperative DLCO%; KL-6: sialylated carbohydrate antigen krebs von den lungen-6; SP-D: pulmonary surfactant protein-D; SP-A: pulmonary surfactant protein-A; PA plasty: pulmonary artery plasty; PGA sheet: polyglycolic acid sheet; BAC: bronchioloalveolar carcinoma; HOT: home oxygen therapy; POD: postoperative day; USD: United States dollar; HG: higher hospitalization cost group; LG: lower hospitalization cost group

(exceeding the third quartile) and lower (less than the third quartile) cost groups since the hospitalization cost consisted of fees for procedures, costs for materials or blood products, or ward charges, it could vary between countries.[6] Our analyses ensured the external validity and interpretation of the current results. As a result, the risk factors for increased hospitalization costs identified in this study ranged widely from baseline patient characteristics and postoperative factors as well as surgical factors.

Several studies identified postoperative complications as a leading factor associated with significantly increased hospitalization cost, some due to a high per-event cost impact and others due to a high complication frequency.[7] Strategies to decrease gross health care expenses should address both types of complications. Pulmonary complications such as prolonged air leaks or pneumonia are relatively frequent complications that contribute to increasing medical costs in accordance with a more extended hospital stay, while the direct costs of its treatment are not so high. Preoperative assessment, procedure selection, careful lobar dissection or lymph node dissection, and thorough leakage control with adequate sealants are indispensable to avoid prolonged air leakage. Furthermore, early detection with a real-time digital air leakage tracking system, such as Thopaz (Medela AG, Baar, Switzerland), and appropriate early intervention are essential to reduce hospitalization costs. Enhanced recovery pathways (ERPs) are introduced in multiple surgical disciplines to protocolize postoperative care. Although the evidence of the ERP in lung resection cases is currently

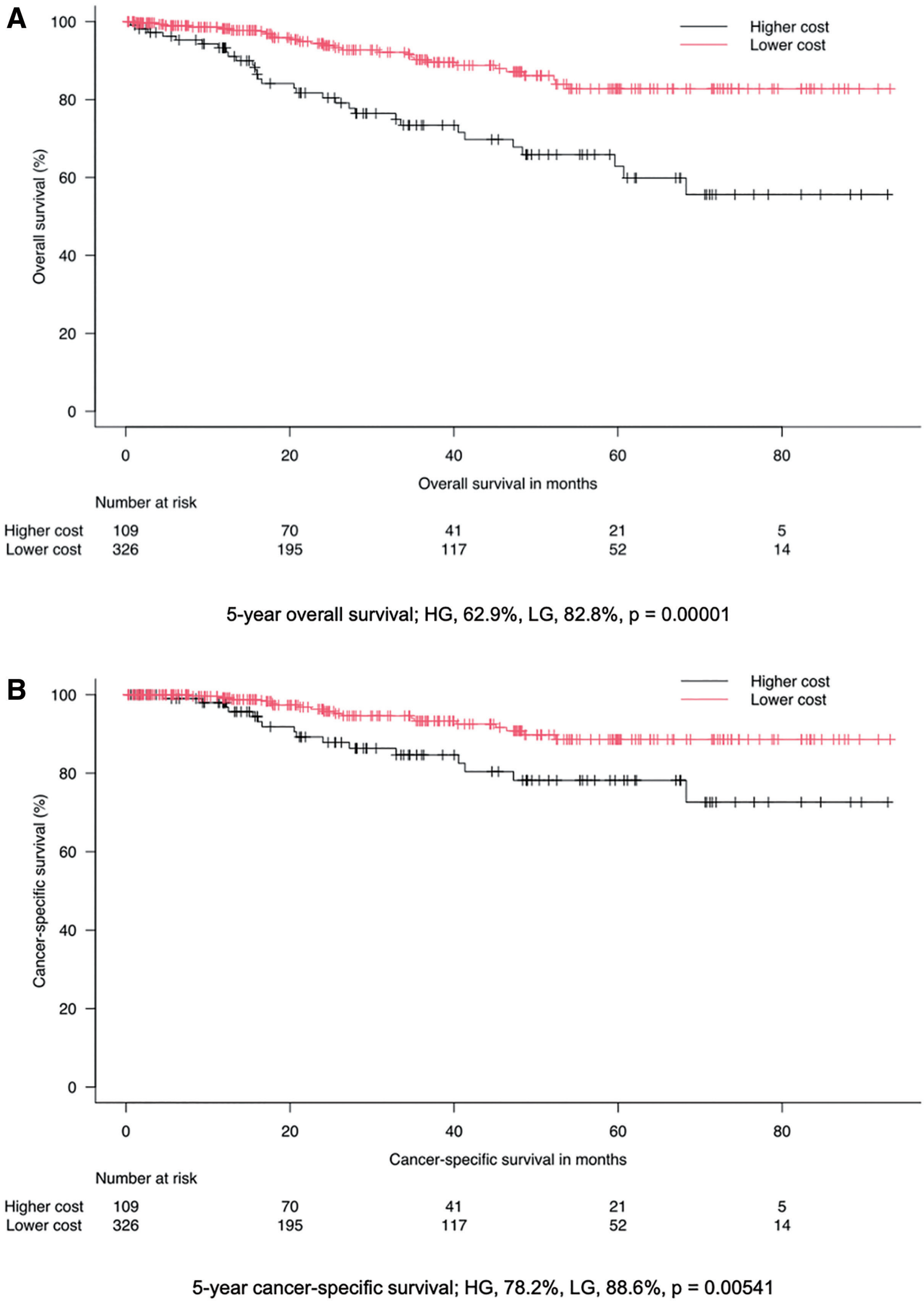

Fig. 1 Overall and cancer-specific survival curves. (**A**) Kaplan–Meier curve of overall survival. (**B**) Kaplan–Meier curve of cancer-specific survival. P-values were calculated using log-rank tests. HG: higher hospitalization cost group; LG: lower hospitalization cost group

insufficient, early mobilization under the ERP in conjunction with preoperative smoking cessation might contribute significantly to avoiding postoperative pneumonia. On the other hand, several reports revealed that prevention of postoperative atrial fibrillation and control of postoperative pain contribute to shortening the postoperative hospital stay. Establishing the patient care pathway, addressing all these issues, and continuous improvement with feedback are necessary to ensure clinical outcomes and medical cost reduction.

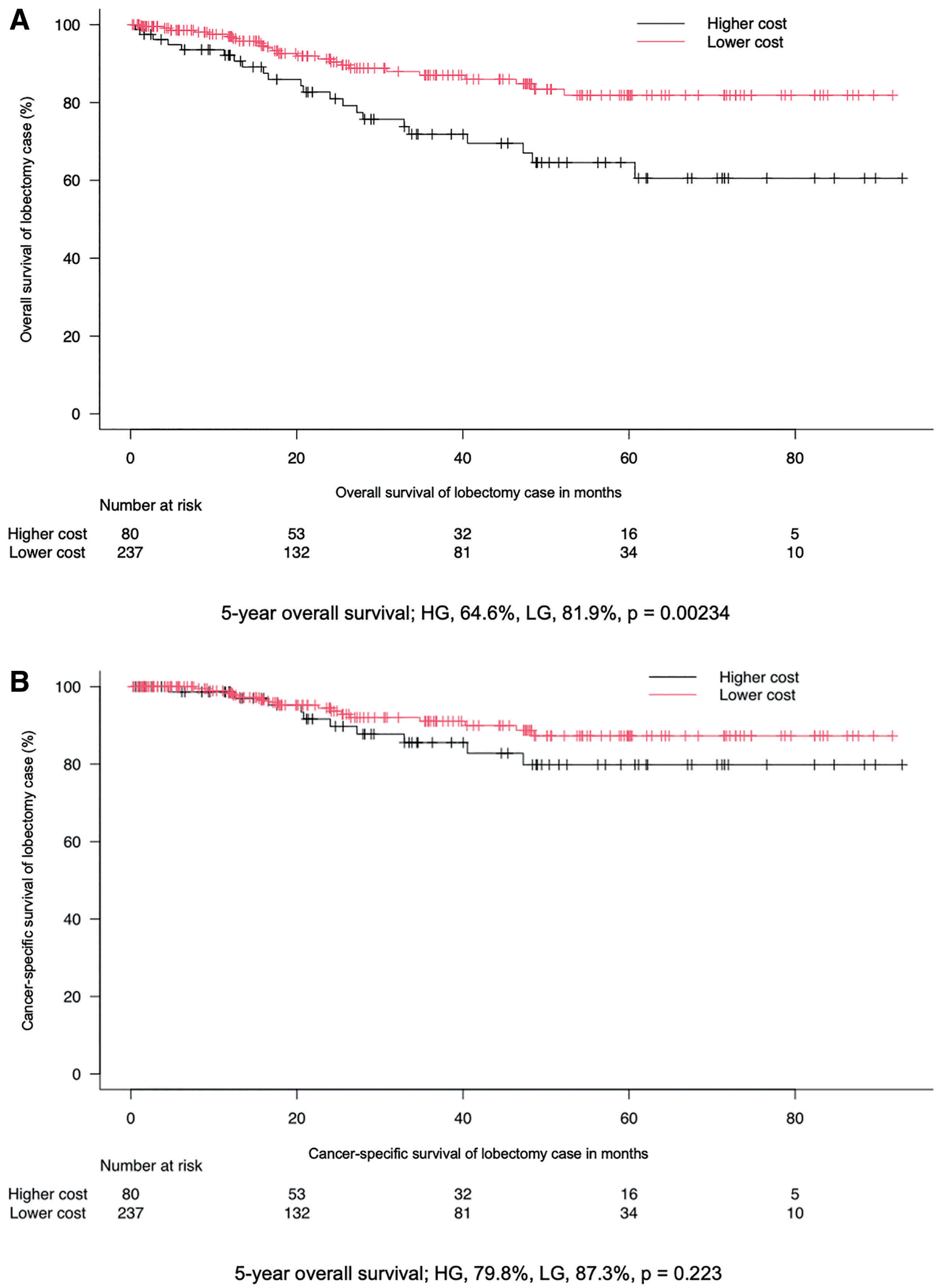

Fig. 2 Overall and cancer-specific survival curves of lobectomy cases. (**A**) Kaplan–Meier curve of overall survival. (**B**) Kaplan–Meier curve of cancer-specific survival. P-values were calculated using log-rank tests. HG: higher hospitalization cost group; LG: lower hospitalization cost group

Regarding baseline patient characteristics, Brunelli et al. reported thoracotomy, respiratory function, and coronary artery disease as preoperative factors to estimate the hospitalization cost for lung resection.[8] In addition to those factors, significant differences were observed in this study in gender, smoking history, neoadjuvant chemo-/radio-therapy, tumor factor in TNM classification, and histological classification between higher and lower cost groups. Especially regarding smoking, along with preoperative smoking cessation, further social awareness should be promoted to avoid the initiation and habituation of smoking.

Among surgical factors affecting higher cost, type of procedure, use of sealants, transfusion and additional procedures, operation time were essential. Therefore, feedback on selecting surgical strategies can be crucial, especially in complicated and time-consuming cases. Careful and precise procedures should be performed to prevent blood transfusions or prolonged air leakage.

According to the sub-analysis limited to lobectomy cases, common factors that increased hospitalization cost in overall cases and lobectomy cases in multivariate analysis were smoking history, COPD, CAD, previous thoracotomy, squamous cell carcinoma, transfusion, prolonged PHS, and postoperative complications. While several unavoidable preoperative comorbidities were identified as risk factors, transfusion and postoperative complications were also identified as risk factors for higher hospitalization costs. On the other hand, the mutual factors that increased the hospitalization cost or prolonged the postoperative hospital stay in lobectomy cases were squamous cell carcinoma, prolonged operation time (>3 hours), and postoperative complications. Again, the importance of social awareness for smoking cessation and primary prevention of lifestyle-related diseases, as well as the requirement for further surgical refinement and more sophisticated postoperative management, were suggested.

Although we collected comprehensive data from 2011 to 2019 and carefully analyzed in this study, there were some limitations. First, it was a retrospective study. Second, the medical insurance system and socio-economic background differ between countries. Third, surgical procedures and pathological stages varied in this study. While significant differences in overall- and cancer-specific survival between groups were observed in this study, it was difficult to obtain its speculations due to this limitation. Fourth, the medical fee and DPC coefficients are revised every two years and every year, respectively. However, the hospitalization expenses in this study were described according to the medical expenses billed at the time of discharge for each case.

Future comprehensive research that integrates risk analysis of postoperative complications and prolonged hospital stay, as well as propensity score match analysis, will be necessary.

There are particular biases related to hospital profits or patients' demands in the real world. Currently, complete elimination of the influence of these biases is impossible. However, as in the present study, recognizing and giving feedback on a higher-cost patient subset might help healthcare administrators tailor future individualized lung resection reimbursement tariffs. Repeating this feedback would potentially converge to a specific situation satisfying clinical and socio-economic outcomes, even including these biases.

Conclusion

Higher hospitalization cost for lung resection in a setting of relatively uniform procedural strategy by a single surgeon at a single institution was related to not only postoperative complications and baseline patient factors but also operative factors. In addition to socially intervenable preoperative factors, further appropriate surgical strategy reflecting the clinical feedback and continuous efforts to reduce postoperative complications would significantly reduce healthcare spending.

Declarations

Ethics approval and consent to participate

This study was conducted according to the principles outlined in the Declaration of Helsinki and the guidelines of the research ethics committee of Gifu Prefectural General Medical Center, and approved by the institutional review board, and informed consent was obtained in the form of opt-out on the website (GPGMC IRB-611).

Consent for publication

Consent for manuscript publication was also obtained in the form of an opt-out on the website.

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Data availability statement

The data associated with the paper are not publicly available but are available from the corresponding author on reasonable request.

Authors' contributions

All authors have contributed equally to this work. Yukio Umeda: conceptualization, data curation, formal analysis, investigation, methodology, project administration, and writing the original draft; Shinsuke Matsumoto and Kiyohiko Hagiwara: supervision; Shoji Yoshikawa: supervision on statistical analysis, and Alex Chen: writing—review and editing.

Disclosure statement

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