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ORIGINAL ARTICLE

# The maximum dimension of the inferior vena cava is a significant predictor of postoperative mortality in lung cancer patients with idiopathic interstitial pneumonia

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## Abstract

**Purpose** Several vascular measurements in computed tomography (CT) were reported to be indicators of pulmonary hypertension in chronic obstructive pulmonary disease (COPD) patients. We evaluated the usefulness of these parameters as predictors of postoperative mortality in lung cancer patients with IIP.

**Methods** This retrospective study was performed on 1888 patients. The following CT findings were evaluated: diameter of the main pulmonary artery, ascending aorta, and the short axis of the inferior vena cava (IVC). Univariate and multivariate analyses were conducted to determine predictors of surgical mortality.

**Results** In the IIP patients, the 90-day mortality was 0.8%, and the 2-year mortality was 5.8%. Regarding the 90-day mortality in patients with IIP, a multivariate analysis revealed a short axis of IVC > 21 mm [odds ratio (OR) 6.4, $p < 0.01$) and the risk score reported by Japanese Association for Chest Surgery (JACS) (OR 1.4, $p = 0.01$) as independent predictors. Regarding the 2-year mortality in patients with IIP, a multivariate analysis revealed IVC > 21 mm (OR 2.3, $p < 0.04$), %VC < 80% (OR 2.4, $p = 0.02$), and pathological cancer stages II and III vs. I (OR 7.2, $p < 0.001$) as independent predictors.

**Conclusions** Enlargement of the IVC as measured by CT was a significant predictor of mortality after surgery for lung cancer with IIP patients.

**Keywords** Inferior vena cava · Idiopathic interstitial pneumonia · Lung cancer · Surgical mortality

## Introduction

The prognosis of lung cancer patients with idiopathic interstitial pneumonia (IIP) has been reported to be poor, and the indications for surgical resection should be carefully considered [1–3]. Furthermore, such indications should be determined based on cancer progression and the state of IIP. Regarding the state of IIP, the risk of acute exacerbation after surgery as well as the prognosis and severity of IIP per se influence decision-making.

Pulmonary hypertension (PH) is reported to be associated with an increased risk of mortality in patients with pulmonary fibrosis [4, 5]. However, it is unusual to evaluate PH and the right heart function by echocardiogram or catheterization of the heart before surgery. Regarding the evaluation of PH, several papers have described the usefulness of measuring diameter of the main pulmonary artery (MPAD) or MPAD/aorta ratio (PA–Ao ratio) on computed tomography (CT) in chronic obstructive pulmonary disease (COPD) patients [6, 7]. However, there are no data concerning the relationship between those vascular measurements on CT with IIP. Furthermore, there are no reports on the dimension of the inferior vena cava (IVC), despite its importance in echo diagnoses. In trauma patients, the diameter of the IVC on CT rather than an echogram was reported to be useful

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for evaluating hypovolemia [8, 9]. The measurement of the MPA and IVC may be able to be applied for the preoperative assessment of right heart load in patients with IIP and to predict the prognosis of lung cancer patients with IIP.

We therefore conducted a retrospective study of patients with lung cancer concomitant with IIP based on preoperative factors, including several vascular measurements on CT, and found that the preoperative radiological vascular dimensions were useful for predicting surgical mortality after pulmonary resection for lung cancer with IIP.

## Methods

### Study population

A retrospective study was performed on 1888 patients with clinical stage I–III lung cancer who underwent pulmonary resection between January 2009 and December 2015 at our institute. All patients underwent a preoperative thoracic CT scan performed with a slice thickness of ≤ 2 mm using mediastinal [level of 40 Hounsfield units (HU), width of 400 HU] and lung (level of 600 HU, width of 1600 HU) window settings. All CT findings were reviewed anew by the authors (two radiologists: Kazuhiro Suzuki and Akihiro Hotta; one pulmonary medicine physician: Kazuhiro Ando; two thoracic surgeons: Mariko Fukui and Kazuya Takamochi). We diagnosed IIP based on the reported criteria [10–12] and classified patients into three groups: usual interstitial pneumonia (UIP) pattern, possible UIP pattern, and inconsistent with UIP pattern based on the official the American Thoracic Society (ATS)/the European Respiratory Society (ERS)/the Japanese Respiratory Society (JRS)/the Latin American Thoracic Association (ALAT) statement [4]. Patients with a reticular shadow, which may be attributed to a displaced lung by osteophytes or self-weight consolidation, were excluded from the IIP groups. The presence of emphysema was also evaluated, and a positive diagnosis was made when the emphysema area accounted for more than 10% of the lungs. We excluded patients for whom pulmonary resection was cancelled due to dissemination ($n = 37$) and those who received chemotherapy or radiotherapy ($n = 83$) to exclude interstitial lung disease from known causes (Fig. 1).

The preoperative evaluation included a complete history, physical examination, laboratory findings, arterial blood gas analysis, chest X-ray, and pulmonary function tests, as well as CT of the chest and abdomen, electrocardiogram, and echocardiogram for patients with an abnormal electrocardiogram (ECG) or a history of heart disorder. We also used a scoring system (JACS score) for predicting acute exacerbation of IIP after pulmonary resection in lung cancer patients [13].

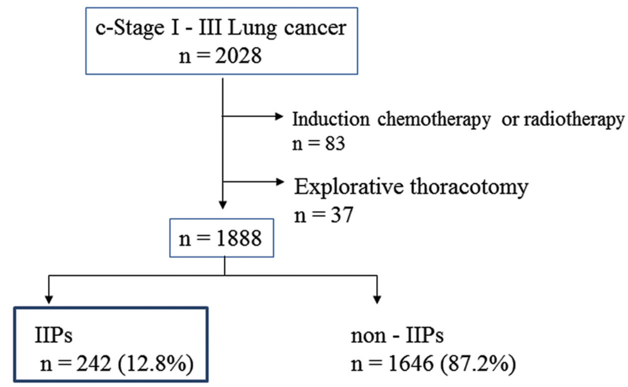


**Fig. 1** The demographics of the patients in the present study

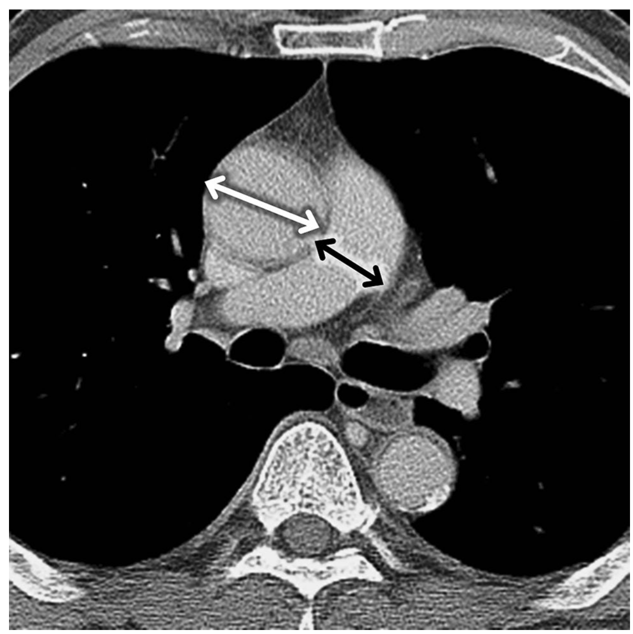

**Fig. 2** The diameter of the main pulmonary artery at the level of its bifurcation (black line) was evaluated. The ascending aorta in the same image (white line) was used for measuring the diameter of the aorta (Ao)

In the present study, the same surgical team performed all of the surgeries and coordinated the perioperative management for all patients. Details of our management have been reported previously [14].

### The radiological measurement of the vascular diameter

The factors we used as indices of the right-side cardiac pressure were the main pulmonary artery diameter (MPAD), which is measured as the diameter of the main pulmonary artery at the level of its bifurcation (Fig. 2); the ratio of the

MPAD to the diameter of the aorta at the same level of the MPAD (PA–Ao ratio); and the maximum dimension of the IVC, which is measured as the short axis of the IVC between the left atrium and hepatic vein (Fig. 3).

### Definition of surgical outcomes

Operative mortality was defined as death within 30 and 90 days of resection. Postoperative complications were defined to include hypoxia requiring home oxygen therapy, acute lung injury (ALI), pneumonia, intractable air leakage requiring adhesion therapy or additional drainage, bronchopleural fistula proven by bronchoscope or operative findings of leakage, empyema, arrhythmias, and acute exacerbation of IIP (defined as worsening of dyspnea and hypoxia from baseline within 30 days, including new ground-glass abnormality and/or consolidation superimposed on a background reticular or honeycombing pattern). Findings with alternative causes, such as left heart failure, aspiration pneumonia, pulmonary embolism, or identified causes of acute lung injury, were excluded from acute exacerbation of IIP. Respiratory morbidity in this study was defined as acute exacerbation of IIP, hypoxia, ALI, and pneumonia.

### Statistical analyses

Predictors of the 90-day mortality were determined by univariate and multivariate analyses using a logistic regression model. Survival curves were estimated using the Kaplan–Meier method. Predictors of the 2-year survival were investigated by univariate and multivariate analyses using Cox's proportional hazard model.

All of the statistical analyses were performed using the SPSS 24.0 software program (SPSS Inc., Chicago, IL, USA). $P$ values of $<0.05$ were considered to indicate statistical significance.

This study was approved by the ethics committee at our institute (2015015).

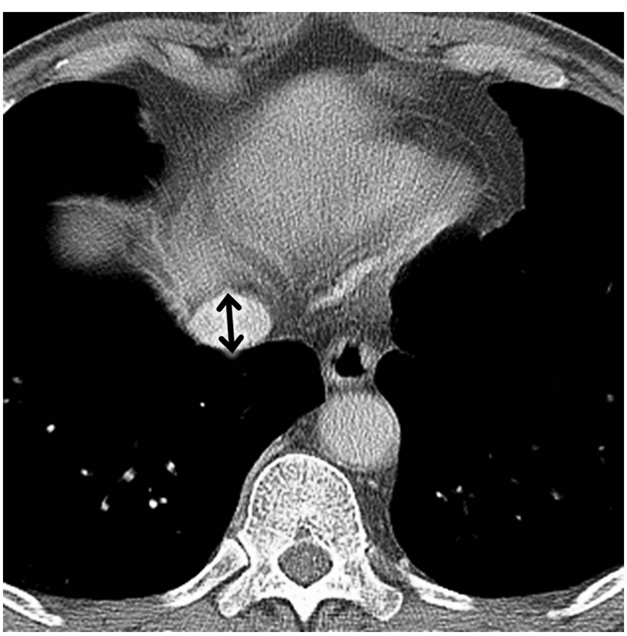

**Fig. 3** The short axis of the inferior vena cava (IVC) between the left atrium and hepatic vein was measured as the short axis of the IVC

## Results

The clinical characteristics of the IIP patients are shown in Table 1. Men and severe smokers were dominant, and the average percentage of diffusing capacity of the lung for carbon monoxide (%DLCO) was 44.2% ± 15.8%. Emphysema was a complication in 52.5% patients with IIP. Regarding the surgical procedure, lobectomy or more centered on complete resection was performed in 82.6% of cases.

Table 2 shows the dimensions of MPA, IVC, and Ao on CT. These average values are roughly the same as previously reported (MPA in COPD: 28.7 mm, MPA in non-COPD: 25.3 mm) [7]. Forty-five patients (18.6%) underwent echocardiography, including 8 patients with an IVC of > 21 mm on CT and 1 who was diagnosed with PH by echocardiography. Among the patients with an IVC dimension of ≤ 21 mm, none had PH.

Morbidities within 30 days and mortality after surgery were reviewed and are presented in Table 3. Acute exacerbation of IIP occurred in 11 patients (4.5%). The 90-day mortality was 5.8%. Causes of death within 90 days were acute exacerbation of IIP ($n=4$), respiratory failure ($n=2$), pneumonia ($n=1$), sudden death of unknown cause ($n=2$) and cancer ($n=5$).

The 2-year overall survival was 68.0%, and the 2-year cancer-specific survival was 81.0%. The survival and cancer-specific survival of patients with larger IVCs (> 21 mm) was not significantly different from those of patients with normal IVCs (≤ 21 mm) (log-rank test, $p=0.0518$ and $p=0.4677$). The 2-year survival rates of patients with larger and normal IVCs were 55.6% and 71.5%, respectively.

Among patients with IIP, the following predictors of 90-day mortality were identified based on a univariate analysis: JACS score, diffuse and central extension of IIP, preoperative arterial blood gas < 70 mmHg, %VC < 80%, clinical cancer stage (I vs. II and III), and dimension of MPAD > 29 mm, and IVC > 21 mm. A multivariate analysis revealed that the JACS score [odds ratio (OR) 1.401, 95% confidence interval (CI) 1.082–1.813] and IVC > 21 mm (OR 6.896, 95% CI 1.969–24.154) were predictors of 90-day mortality (Table 4). Regarding the 2-year mortality in patients with IIP, a multivariate analysis revealed IVC > 21 mm (OR 2.333, 95% CI 1.283–4.242), %VC < 80%

**Table 1** Baseline characteristics of the patients

| Variables | | |
|---|---|---|
| Number of patients | 242 | (%) |
| Age (years) | 71.9 ± 7.3 | |
| Age > 75 years (*n*) | 93 | (38.4) |
| Gender: male (*n*) | 196 | (81.0) |
| Smoking history (pack-years) | 51.3 ± 36.5 | |
| CEA (ng/mL) | 10.1 ± 25.5 | |
| Preoperative LDH (IU/L) | 208.8 ± 51.3 | |
| Preoperative KL-6 (U/mL) | 574.0 ± 373.9 | |
| FVC (L) | 3.13 ± 0.77 | |
| %VC | 96.3 ± 17.8 | |
| %VC < 80% | 44 | (18.2) |
| FEV1.0/FVC (L) | 2.13 ± 0.51 | |
| FEV1.0/FVC < 0.7 | 89 | (36.8) |
| $\%D_{LCO}$ | 44.2 ± 15.8 | |
| %DLCO < 40% | 85 | (35.1) |
| $pO_2$ (mmHg) | 83.8 ± 10.5 | |
| $pO_2$ < 70 mmHg | 20 | (8.3) |
| Radiological type of IIP | | |
| UIP pattern/possible UIP | 90 | (37.2) |
| Inconsistent with UIP | 152 | (64.8) |
| Emphysema (CPFE) | 127 | (52.5) |
| Distribution (diffuse) | 95 | (39.3) |
| Diffuse and central extension of IP | 36 | (14.9) |
| JACS score | 7.3 ± 3.0 | |
| 0–10 | 163 | (67.4) |
| 11–14 | 64 | (26.4) |
| ≥ 15 | 0 | |
| No data | 14 | |
| Clinical stage | | |
| Stage I | 168 | (69.4) |
| Stage II or III | 74 | (30.6) |
| Pathological stage | | |
| Stage I | 124 | (51.3) |
| Stage II or III | 116 | (47.9) |
| Histology of lung cancer | | |
| Squamous cell carcinoma | 105 | (43.4) |
| Non-squamous cell carcinoma | 137 | (56.6) |
| Procedure | | |
| Lobectomy or more | 200 | (82.6) |
| Limited resection | 42 | (17.4) |

*CEA* carcinoembryonic antigen, *LDH* lactate dehydrogenase, *KL-6* sialylated carbohydrate antigen, *VC* vital capacity, *FEV1.0* Forced expiratory volume in one second, *%DLCO* percentage of diffusing capacity of the lung for carbon monoxide, *JACS* Japanese Association for Chest Surgery

[a]*p* value in the *t* test

[b]*p* value in Chi-square test

**Table 2** Measurement of dilatation MPA, IVC, Ao on computed tomography

| Variables | |
|---|---|
| Number of patients | 242 |
| IVC > 21 mm | 37 (15.5%) |
| IVC > 25 mm | 4 (1.6%) |
| MPAD > 29 mm | 40 (16.5%) |
| MPAD/Ao > 1.0 | 16 (6.6%) |
| Average value | |
| MPAD | 26.0 ± 3.6 |
| Ao | 34.5 ± 3.8 |
| IVC | 18.0 ± 3.5 |
| MPAD/Ao | 0.76 ± 0.12 |
| IVC/Ao | 0.52 ± 0.14 |

*MPAD* main pulmonary artery diameter at the level of its bifurcation, *Ao* diameter of the ascending aorta is at the same level of MPAD, *IVC* maximum diameter of the inferior vena cava between the hepatic vein and left atria

**Table 3** Morbidities within 30 days and mortalities after surgery

| Variables | Total |
|---|---|
| Number of patients | 242 |
| Morbidities | |
| Acute exacerbation of IIP | 11 (4.5%) |
| Hypoxia that required home oxygen therapy | 51 (21.1%) |
| Pneumonia | 11 (4.5%) |
| Intractable air leakage | 19 (7.9%) |
| Bronchopleural fistula | 7 (2.8%) |
| Empyema | 4 (1.7%) |
| Arrhythmias | 31 (12.8%) |
| 30-day mortality | 2 (0.8%) |
| 90-day mortality | 14 (5.8%) |
| 2-year mortality | 68 (28.1%) |

[a]*p* value in the Chi-square test

[b]Respiratory morbidity: acute exacerbation of idiopathic interstitial pneumonia (IIP), hypoxia, acute lung injury (ALI) and pneumonia

(OR 1.916, 95% CI 1.099–3.341), diffuse and central extension of IIP (OR 2.012, 95% CI 1.077–3.760), and pathological cancer stage II and III vs. I (OR 6.206, 95% CI 3.302–11.664) as independent predictors (Table 5).

Table 6 shows the clinicopathological characteristics classified by the IVC diameter. The two IVC groups were similar in their age, rate of emphysema, clinical and pathological stage of lung cancer, and JACS score. The percentages of patients with hypoxia ($pO_2 < 70$ mmHg) in the IVC > 21 mm and ≤ 21 mm groups were 17.8% and 6.3%, respectively ($p = 0.013$). The percentages of patients with restrictive lung disease (%VC < 80%) in the IVC > 21 mm and ≤ 21 mm groups were 33.3% and 14.1%, respectively ($p = 0.003$).

**Table 4** Results of univariate and multivariate analyses to identify the 90-day mortality in IIP patients

| | Univariate analysis | | | Multivariate analysis | | |
|---|---|---|---|---|---|---|
| Variables | Odds ratio | 95% CI | *p* value[a] | Odds ratio | 95% CI | *p* value |
| Age > 75 years | 0.712 | 0.217–2.343 | 0.712 | | | |
| Gender: male | 499.021 | 0.000 | 0.997 | | | |
| JACS score | 1.367 | 1.076–1.736 | 0.011 | 1.401 | 1.082–1.813 | 0.010 |
| UIP pattern | 1.241 | 0.945–1.631 | 0.121 | | | |
| Diffuse and central extension of IIP | 3.403 | 1.072–10.804 | 0.038 | | | |
| KL-6 ≥ 1000 IU/L | 2.653 | 0.502–14.028 | 0.251 | | | |
| $pO_2$ < 70 mmHg | 3.369 | 1.857–13.244 | 0.042 | | | |
| %VC < 80% | 4.286 | 1.364–13.464 | 0.013 | | | |
| FEV1.0/FVC < 0.7 | 0.492 | 0.132–1.837 | 0.291 | | | |
| %DLCO < 40% | 3.247 | 0.946–11.145 | 0.061 | | | |
| Surgical procedure | 1.063 | 0.724–1.560 | 0.755 | | | |
| Cancer stages c-II and III vs. I | 3.273 | 1.093–9.768 | 0.034 | | | |
| MPAD > 29 mm | 4.279 | 1.397–13.109 | 0.011 | | | |
| MPAD/Ao ratio > 1.0 | 2.548 | 0.519–12.513 | 0.249 | | | |
| IVC > 21 mm | 6.400 | 2.096–19.538 | 0.001 | 6.896 | 1.969–24.154 | 0.003 |

*JACS* Japanese Association for Chest Surgery, *UIP* usual interstitial pneumonia, *KL-6* sialylated carbohydrate antigen, *VC* vital capacity, *FEV1.0* Forced expiratory volume in one second, *%DLCO* percentage of diffusing capacity of the lung for carbon monoxide, *MPAD* main pulmonary artery diameter at the level of its bifurcation, *Ao* diameter of the assending aorta is at the same level of MPAD, *IVC* maximum diameter of the inferior vena cava between the hepatic vein and left atria

[a]*p* value in the logistic regression test

**Table 5** Results of univariate and multivariate analyses to identify the two-year mortality in IIP patients

| | Univariate analysis | | | Multivariate analysis | | |
|---|---|---|---|---|---|---|
| Variables | Odds ratio | 95% CI | *p* value[a] | Odds ratio | 95% CI | *p* value |
| Age > 75 years | 0.883 | 0.531–1.467 | 0.631 | | | |
| Gender: male | 1.346 | 1.037–1.747 | 0.026 | | | |
| UIP pattern | 1.173 | 1.042–1.322 | 0.008 | | | |
| Diffuse and central extension of IIP | 1.847 | 1.041–3.277 | 0.036 | 2.012 | 1.077–3.760 | 0.028 |
| KL-6 ≥ 1000 IU/L | 1.867 | 0.832–4.193 | 0.136 | | | |
| $pO_2$ < 70 mmHg | 1.099 | 0.404–2.989 | 0.853 | | | |
| %VC < 80% | 2.629 | 1.567-4/4-0 | < 0.001 | 1.916 | 1.099–3.341 | 0.022 |
| FEV1.0/FVC < 0.7 | 0.602 | 0.350–1.035 | 0.602 | | | |
| %DLCO < 40% | 1.369 | 0.820–2.286 | 0.229 | | | |
| Surgical procedure | 1.210 | 0.619–2.368 | 0.577 | | | |
| Cancer stages *p*-II and III vs. I | 4.376 | 2.493–7.681 | < 0.001 | 6.206 | 3.302–11.664 | < 0.001 |
| MPAD > 29 mm | 1.458 | 0.832–2.553 | 0.203 | | | |
| MPAD/Ao ratio > 1.0 | 0.924 | 0.336–2.537 | 0.878 | | | |
| IVC > 21 mm | 1.968 | 1.143–3.390 | 0.015 | 2.333 | 1.283–4.242 | 0.005 |

*UIP* usual interstitial pneumonia, *KL-6* sialylated carbohydrate antigen, *VC* vital capacity, *FEV1.0* Forced expiratory volume in one second, *%DLCO* percentage of diffusing capacity of the lung for carbon monoxide, *MPAD* main pulmonary artery diameter at the level of its bifurcation, *Ao* diameter of the assending aorta is at the same level of MPAD, *IVC* maximum diameter of the inferior vena cava between the hepatic vein and left atria

[a]*p* value in the logistic regression test

**Table 6** A comparison of characteristics between patients with IVC > 21 and ≤ 21 mm

| Variables | IVC ≤ 21 mm | IVC > 21 mm | p |
|---|---|---|---|
| Number of patients | 191 (%) | 45 (%) | |
| Age (years) | 71.7 ± 7.5 | 71.8 ± 6.9 | 0.935 |
| Age > 75 years (*n*) | 64 (33.5) | 18 (40.0) | 0.411 |
| Gender: male (*n*) | 152 (79.6) | 40 (88.9) | 0.149 |
| Smoking history (pack-years) | 45.6 ± 39.9 | 48.0 ± 41.5 | 0.723 |
| CEA (ng/mL) | 10.6 ± 28.0 | 8.9 ± 12.7 | 0.708 |
| Preoperative LDH (IU/L) | 207.1 ± 43.4 | 216.3 ± 79.1 | 0.347 |
| Preoperative KL-6 (U/mL) | 576.8 ± 389.8 | 580 ± 348.9 | 0.960 |
| FVC (L) | 3.16 ± 0.75 | 3.14 ± 0.82 | 0.912 |
| %VC | 97.2 ± 16.9 | 93.4 ± 17.5 | 0.189 |
| %VC < 80% | 27 (14.1) | 15 (33.3) | 0.003 |
| FEV1.0/FVC (L) | 2.17 ± 0.49 | 2.02 ± 0.53 | 0.059 |
| FEV1.0/FVC < 0.7 | 69 (36.1) | 19 (42.2) | 0.396 |
| $\%D_{LCO}$ | 45.2 ± 15.8 | 40.3 ± 16.1 | 0.088 |
| %DLCO < 40% | 60 (31.4) | 20 (44.4) | 0.093 |
| $pO_2$ (mmHg) | 84.6 ± 10.5 | 80.3 ± 9.9 | 0.012 |
| $pO_2$ < 70 mmHg | 12 (6.3) | 8 (17.8) | 0.013 |
| Radiological type of IIPs | | | 0.033 |
| UIP pattern/possible UIP | 65 (34.0) | 23 (51.1) | |
| Inconsistent with UIP | 126 (66.0) | 22 (48.9) | |
| Emphysema (CPFE) | 97 (50.8) | 29 (64.4) | 0.098 |
| Diffuse and central extension of IP | 26 (13.6) | 7 (15.6) | 0.735 |
| JACS score | 7.5 ± 2.9 | 8.0 ± 2.8 | 0.315 |
| Clinical stage | | | 0.698 |
| Stage I | 133 (69.6) | 30 (66.7) | |
| Stage II or III | 58(30.4) | 15 (33.3) | |
| Pathological stage | | | 0.350 |
| Stage I | 94 (49.2) | 25 (55.6) | |
| Stage II or III | 93 (48.7) | 18 (40.0) | |
| Histology of lung cancer | | | 0.012 |
| Squamous cell carcinoma | 116 (60.7) | 18 (40.0) | |
| Non-squamous cell carcinoma | 75 (39.3) | 27 (60.0) | |

*CEA* carcinoembryonic antigen, *LDH* lactate dehydrogenase, *KL-6* sialylated carbohydrate antigen, *VC* vital capacity, *FEV1.0* Forced expiratory volume in one second, *%DLCO* percentage of diffusing capacity of the lung for carbon monoxide, *JACS* Japanese Association for Chest Surgery

[a] *p* value in the *t* test

[b] *p* value in Chi-square test

## Discussion

Several previous reports have concluded that pulmonary resection for lung cancer complicated with IIP carries an extremely high risk and a poor prognosis [10, 15].

In the short term, the coexistence of IIP increases the risk of postoperative morbidity, such as acute exacerbation (AE) of IIP, pneumonia, bronchopleural fistula, and respiratory failure [1–3, 10]. The largest study of the surgical outcome of patients with lung cancer and IIP was conducted by the Japanese Association for Chest Surgery [10]. This study, which included 1763 patients, reported a 30-day mortality of 2.6% and an AE rate of 9.3%. The following seven predictors of AE were reported within 30 days after surgery: surgical procedure, gender, history of exacerbation, preoperative steroid use, serum KL-6 levels, IP pattern on CT, and percent predicted vital capacity. Sato reported a simple risk score (JACS score) [13] using these data. In our study, the JACS score was useful for predicting the short-term mortality after surgery. Although many useful reports have been published, the investigable factors depend on the preoperative examination of lung cancer. The factors that are not common as preoperative examination are not usually evaluated even if it was reported to be important factor on the estimation severity of IIPs. As such, the information including desaturation on exercise, %DLCO, and PH evaluated by echocardiography tend to be missing.

In the long term, the predictors of the prognosis of lung cancer patients with IIP are the cancer stage and natural history of IIP. Features associated with an increased risk of mortality in idiopathic pulmonary fibrosis are a %DLCO < 40% of the predicted value, desaturation of < 88% during 6-minute walk test, extent of honeycombing on high-resolution CT, and PH [4]. PH is the most important factor that has been detected in many reports [16, 17], but it is rarely evaluated before lung cancer surgery. Detecting the effect PH by CT would be very meaningful, as CT in the inspiration phase is required before lung cancer surgery.

The dimensions of MPA and the PA–Ao ratio on CT were reported to be predictors of the outcome in COPD patients [6, 7, 18, 19]. However, in the present study, the MPAD and PA–A ratio was not significant predictors among IIP patients in a multivariate analysis. IIP patients are reported to have 1.5- to twofold greater risk of complication by arteriosclerosis than non-IIP patients [20, 21], and the MPAD and PA–Ao ratio may differ substantially among individuals. In our study, the IVC diameter may have indicated the severity of pulmonary fibrosis. However, the IVC dimension is a relatively new factor, it could easily be measured during inspiration on CT. And it is likely less affected by other complications such as arteriosclerosis. The cut-off value in this study was > 21 mm, which was also used in the assessment by echocardiogram [22, 23]. This indicator closely reflected the prognosis after surgery in lung cancer patients with IIP.

This study is limited by its single-center design and retrospective nature. As such, the details of the operative procedures may vary between institutes, and this limits the generalizability of our findings. Another limitation involves the radiological evaluation, as there was some controversy between the observers in the radiological evaluation of the type of IIP and the vascular dimensions.

However, despite these limitations, we conclude that enlargement of the IVC was a significant predictor of the 90-day and 2-year mortality among IIP patients. Measuring the IVC by CT is expected to be simple and useful for these patients.

### Compliance with ethical standards

**Conflict of interest** None declared.

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