Prognostic Marker for Severe Acute Exacerbation of Chronic Obstructive Pulmonary Disease: Analysis of Diffusing Capacity of the Lung for Carbon Monoxide (DLCO) and Forced Expiratory Volume in One Second (FEV1)

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Abstract

**Background:** It is important to assess the prognosis and classify patients in chronic obstructive pulmonary disease (COPD) and acute exacerbation of COPD (AECOPD) treatment. Recently, it was suggested that diffusing capacity of the lung for carbon monoxide (D\textsubscript{LCO}) should be added to multidimensional tools for assessing COPD. This study aimed to compare the D\textsubscript{LCO} and forced expiratory volume in one second (FEV\textsubscript{1}) to identify better prognostic factors for admitted patients with AECOPD.

**Methods:** We retrospectively analyzed 342 patients with AECOPD receiving inpatient treatment. We classified 342 severe AECOPD events using D\textsubscript{LCO} and FEV\textsubscript{1}. We defined the prognostic factors of severe AECOPD as the length of hospital stay, mortality in hospital, experience of mechanical ventilation, and experience of intensive care unit (ICU) care. We analyzed the prognostic factors by multivariate analysis using logistic regression. In addition, we conducted a correlation analysis and receiver operating characteristic (ROC) curve analysis.

**Results:** In univariate and multivariate analyses, D\textsubscript{LCO} was shown to predict mortality rate (odds ratio = 4.408; 95% confidence interval, 1.070–18.167; \(P = 0.040\)), experience of ventilator (odds ratio = 2.855; 95% confidence interval, 1.216–6.704; \(P = 0.016\)) and ICU (odds ratios = 2.685; 95% confidence interval, 1.290–5.590; \(P = 0.008\)). However, there was no statistically significant difference in mortality rate when using FEV\textsubscript{1} classification (\(P = 0.075\)). In the correlation analysis, both D\textsubscript{LCO} and FEV\textsubscript{1} showed a negative correlation with length of hospital stay. The correlation rate was more pronounced in the D\textsubscript{LCO} (D\textsubscript{LCO}; \(B = -0.103, P < 0.001\)) (FEV\textsubscript{1}; \(B = -0.075, P = 0.007\)). In addition, D\textsubscript{LCO} showed better predictive ability than FEV\textsubscript{1} in ROC curve analysis. The area under the curve (AUC) of D\textsubscript{LCO} was greater than 0.68 for all prognostic factors, and in contrast, the AUC of FEV\textsubscript{1} was less than 0.68.

**Conclusion:** D\textsubscript{LCO} was likely to be as good as or better prognostic marker than FEV\textsubscript{1} in severe AECOPD.

Introduction

Chronic obstructive pulmonary disease (COPD) is a chronic airway disease defined by persistent respiratory symptoms and irreversible airflow limitation.\(^1\)–\(^3\) Patients with COPD present with various symptoms, such as cough, sputum, and dyspnea, and these symptoms are closely related to the quality of life and prognosis.\(^4\),\(^5\) The global initiatives for chronic obstructive lung disease (GOLD) guidelines emphasize treatment based on patient history and symptoms, such as exacerbation history, the modified medical research council dyspnea scale (mMRC), and COPD assessment test (CAT).\(^6\) Forced expiratory volume in one second (FEV\textsubscript{1}) is still used to grade the severity of airflow obstruction, but the 'refined ABCD assessment tool' excludes FEV\textsubscript{1} from the criteria for evaluating the 'ABCD' group. This is because the FEV\textsubscript{1} value is weakly correlated with the patient's symptoms and health status.\(^7\),\(^8\) However, pulmonary function tests (PFT) are still important tests for diagnosing and treating COPD in the clinical field. Therefore, we want other PFT factors related to the patient's symptoms and health status rather than
FEV\textsubscript{1}. Several studies have shown that the diffusing capacity of the lung for carbon monoxide (D\textsubscript{LCO}) among the various values of PFT is closely related to patient symptoms, prognosis, and oxygen demand in COPD\textsuperscript{9,10}. In addition, there was a recent opinion that D\textsubscript{LCO} should be added to multidimensional tools assessing COPD\textsuperscript{11}. This study aimed to compare FEV\textsubscript{1} and D\textsubscript{LCO} through the prognosis of severe acute exacerbations of COPD (AECOPD).

**Method**

**Subjects**

We retrospectively analyzed the medical records of 342 patients admitted to Korea University Guro Hospital from January 2011 to May 2017. We searched our electronic medical records database with the keywords “COPD” and “Acute exacerbation.” This study was approved by the Guro Institutional Review Board. (KUGH16131-002). The requirement for informed consent from the patients was waived due to the retrospective nature of this study.

COPD was diagnosed based on the GOLD guidelines, where the ratio of FEV\textsubscript{1} to forced vital capacity (FVC) was less than 70% in post-bronchodilator spirometry and smokers with at least ten pack-years of tobacco exposure\textsuperscript{6}. AECOPD was defined as worsening of the patient’s respiratory symptoms beyond normal day-to-day variation. Severe AECOPD was defined as ‘if the patient needs hospitalization due to AECOPD.’ Baseline spirometry data used in the analysis were performed in a stable state without acute exacerbation for at least 1 month before admission. Patients were excluded with the following criteria: 1) the cause of admission was not AECOPD; for example, acute heart failure, acute pulmonary edema, acute pulmonary embolism, pneumothorax, and arrhythmia, 2) the patient had cancer, 3) the patient received a major operation within 3 months, 4) the patient had an acute coronary syndrome, brain hemorrhage, or brain infarction within 3 months, 5) the patient had previously been diagnosed with asthma, and 6) the patient had D\textsubscript{LCO} results. All patients were 40 years old or older.

We classified 342 severe AECOPD events using D\textsubscript{LCO} and FEV\textsubscript{1}. When the D\textsubscript{LCO} value is more than 50 (% of predicted value), it is defined as the ‘D\textsubscript{LCO} normal group’ and when it is 50 (% of predicted value) or less, it is defined as the ‘D\textsubscript{LCO} impaired group.’\textsuperscript{11} Likewise, when the FEV\textsubscript{1} value is more than 50 (% of predicted value), it is defined as the ‘FEV\textsubscript{1} normal group’ and when it is 50 (% of predicted value) or less, it is defined as the ‘FEV\textsubscript{1} impaired group’ (Fig. 1).

**Data collection**

We defined the prognostic factors of severe AECOPD as the length of hospital stay, mortality in hospital, experience of mechanical ventilation, and experience of intensive care unit (ICU) care in the hospital. When the patient was hospitalized more than once, only the first hospitalized events were included, and the others were excluded. The following medical data were analyzed: age, sex, smoking history,
comorbidities, baseline spirometry, inhaler and oral medication before admission, length of hospital stay, hospital mortality, experience of mechanical ventilation, and experience of ICU care in hospital.

Statistical analysis

Data were analyzed using SPSS 20 software (SPSS for Windows, SPSS Inc., Chicago, IL, USA). Data are presented as average ± standard deviation or number (percentage). We performed a statistical analysis in two directions. First, two groups were classified using $D_{LCO}$ and $FEV_1$ and analyzed statistically. Continuous variables were compared using the independent t-test, and categorical variables were compared using the chi-squared test. We analyzed the prognostic factors (except length of hospital stay) by multivariate analysis through logistic regression. Multivariate analysis was conducted for variables with a $P$-value of less than 0.05 in the univariate analysis, except for baseline spirometry ($D_{LCO}$ and $FEV_1$). Multivariate analysis was conducted using a backward elimination procedure and was assessed by the Hosmer-Lemeshow test.

Second, the linear correlation between spirometry factors ($D_{LCO}$ and $FEV_1$) and length of hospital stay were analyzed. In univariate analysis, the correlation coefficients between spirometry factors and length of hospital stay were analyzed using the Pearson correlation analysis. In addition, we performed a multivariate linear regression analysis that included variables with a $P$-value of less than 0.05 in the univariate analysis, except baseline spirometry. In addition, multivariate linear regression analysis was conducted using a backward elimination procedure. In the multivariate analysis, $B$ was the regression coefficient, and a negative sign of the regression coefficient meant that the variables were negatively associated.

Third, we used receiver operating characteristic (ROC) curve analysis to predict the sensitivity and specificity of $D_{LCO}$ and $FEV_1$ as prognostic markers in severe AECOPD. A $P$-value of less than 0.05 was considered statistically significant.

Results

Baseline characteristics

Among the 342 events, the $D_{LCO}$ normal group comprised 227 events (the $D_{LCO}$ value was more than 50% of the predicted value), and 115 in the $D_{LCO}$ impaired group. In the $FEV_1$ normal group (the $FEV_1$ value was more than 50% of the predicted value), there was 173 events, and the $FEV_1$ impaired group had 169 events. The average age was 71.5 ± 9.2 years. A total of 238 (69.6%) events were male and 104 (30.4%) were female. Sixty-three (18.4%) events were current smokers and the average pack/year history was 41.3 ± 17.1 years. A total of 225 (65.38) events were using inhalers, and 165 (48.2%) were taking respiratory-related oral medications. Averaged $FEV_1$ was 1.3 ± 0.5 L (54.0 ± 19.3%) and $D_{LCO}$ was 10.6 ± 4.8 L (59.3 ± 21.4%). (Table 1) In both groups, the average length of hospital stay was 10.0 ± 5.1 days.
The mortality rate was 11 (3.2%), the experience of ventilator care was 29 (8.5%), and the experience of ICU care was 39 (11.4%).
|                          | \(D_{\text{LCO}}\) Normal group \((D_{\text{LCO}} > 50, n = 227)\) | \(D_{\text{LCO}}\) Impaired group \((D_{\text{LCO}} \leq 50, n = 115)\) | \(P\)-value | \(\text{FEV}_1\) Normal group \((\text{FEV}_1 > 50, n = 173)\) | \(\text{FEV}_1\) Impaired group \((\text{FEV}_1 \leq 50, n = 169)\) | \(P\)-value | Total \((n = 342)\) |
|---------------------------|----------------------------------------------------------------|----------------------------------------------------------------|--------------|----------------------------------------------------------------|----------------------------------------------------------------|--------------|------------------|
| **Age (years)** †         | 71.1 ± 9.5                                                      | 72.4 ± 8.6                                                      | 0.223        | 72.7 ± 9.8                                                      | 70.4 ± 8.5                                                      | 0.023        | 71.5 ± 9.2       |
| **Sex, no. of exacerbations** |                                                                  |                                                                  |              |                                                                  |                                                                  |              |                  |
| Male‡                    | 144 (63.4%)                                                    | 94 (81.7%)                                                     | 0.001        | 105 (60.7%)                                                    | 133 (78.7%)                                                    | < 0.001      | 238 (69.6%)      |
| Female‡                  | 83 (36.6%)                                                     | 21 (18.3%)                                                     |              | 68 (39.3%)                                                     | 36 (21.3%)                                                    |              | 104 (30.4%)      |
| **Smoking history, no. of exacerbations** |                                                                  |                                                                  |              |                                                                  |                                                                  |              |                  |
| Current smoker‡           | 42 (18.5%)                                                     | 21 (18.3%)                                                     | 0.957        | 32 (18.5%)                                                     | 31 (18.5%)                                                    | 0.971        | 63 (18.4%)       |
| Ex-smoker‡               | 185 (81.5%)                                                    | 94 (81.7%)                                                     |              | 141 (81.5)                                                    | 138 (81.7%)                                                    |              | 279 (81.6%)      |
| Pack-year history †       | 41.1 ± 16.8                                                   | 41.8 ± 17.9                                                   | 0.446        | 40.9 ± 16.5                                                   | 41.7 ± 17.8                                                   | 0.987        |                  |
| **Comorbidities, no. of exacerbations** |                                                                  |                                                                  |              |                                                                  |                                                                  |              |                  |
| Hypertension‡             | 111 (48.9%)                                                   | 53 (46.1%)                                                     | 0.623        | 85 (49.1%)                                                    | 79 (46.7%)                                                    | 0.659        | 164 (48.0%)      |
| Diabetes‡                | 54 (23.8%)                                                     | 25 (21.7%)                                                     | 0.671        | 43 (24.9%)                                                    | 36 (21.3%)                                                    | 0.436        | 49 (23.1%)       |
| Previous TB history‡      | 58 (25.6%)                                                     | 43 (37.4%)                                                     | 0.023        | 35 (20.2%)                                                    | 66 (39.1%)                                                    | < 0.001      | 101 (29.5%)      |

†Numbers are presented as mean ± standard deviation.

‡Numbers are presented as n (%)

Abbreviations: AECOPD, acute exacerbations of chronic obstructive pulmonary disease; LABAs, long acting B agonist bronchodilator; LAMAs, long acting antimuscarinic agent bronchodilator; ICS, inhaled corticosteroids; \(\text{FEV}_1\), forced expiratory volume in one second; \(D_{\text{LCO}}\), diffusing capacity of the lung for carbon monoxide
|                                | \(D_{\text{LCO}}\) Normal group | \(D_{\text{LCO}}\) Impaired group | \(P\)-value | \(\text{FEV}_1\) Normal group | \(\text{FEV}_1\) Impaired group | \(P\)-value | Total (n = 342) |
|--------------------------------|-------------------------------|-------------------------------|-------------|-----------------|-----------------|-------------|----------------|
| Coronary artery disease\(^‡\)  | 37 (16.3%)                   | 17 (14.8%)                   | 0.716       | 32 (18.5%)      | 22 (13.0%)      | 0.165       | 54 (15.8%)    |
| Cerebrovascular accident\(^‡\) | 6 (2.6%)                      | 9 (7.8%)                      | 0.027       | 5 (2.9%)        | 10 (5.9%)       | 0.172       | 15 (4.4%)     |
| Inhaler use before admission   |                              |                              |             |                 |                 |             |                |
| LABAs\(^‡\)                   | 2 (0.9%)                      | 1 (0.9%)                      | 0.015       | 2 (1.2%)        | 1 (0.6%)        | < 0.001     | 3 (0.9%)      |
| LAMAs\(^‡\)                  | 24 (10.6%)                    | 14 (12.2%)                    |             | 27 (15.6%)      | 11 (6.5%)       |            | 38 (11.1%)    |
| LABAs + LAMAs\(^‡\)          | 36 (15.9%)                    | 16 (13.9%)                    |             | 24 (13.9%)      | 28 (16.6%)      |            | 52 (15.2%)    |
| ICS/LABAs\(^‡\)              | 25 (11.0%)                    | 7 (6.1%)                      |             | 21 (12.1%)      | 11 (6.5%)       |            | 32 (9.4%)     |
| Triple therapy\(^‡\)          | 53 (23.3%)                    | 47 (40.9%)                    |             | 32 (18.5%)      | 68 (40.2%)      |            | 100 (29.2%)   |
| None\(^‡\)                   | 87 (38.3%)                    | 30 (26.1%)                    |             | 67 (38.7%)      | 50 (29.6%)      |            | 117 (34.2%)   |
| Oral medication before admission |                              |                              |             |                 |                 |             |                |
| Oral \(\beta_2\) adrenoreceptor agonist\(^‡\) | 8 (3.5%)                      | 19 (16.5%)                    | < 0.001     | 9 (5.2%)        | 18 (10.7%)      | 0.062       | 27 (7.9%)     |
| Rofilumast\(^‡\)             | 7 (3.1%)                      | 10 (8.7%)                     | 0.024       | 1 (0.6%)        | 16 (9.5%)       | < 0.001     | 17 (5.0%)     |

\(^‡\)Numbers are presented as mean ± standard deviation.

\(^‡\)Numbers are presented as n (%)

Abbreviations: AECOPD, acute exacerbations of chronic obstructive pulmonary disease; LABAs, long acting B agonist bronchodilator; LAMAs, long acting antimuscarinic agent bronchodilator; ICS, inhaled corticosteroids; \(\text{FEV}_1\), forced expiratory volume in one second; \(D_{\text{LCO}}\), diffusing capacity of the lung for carbon monoxide
Prognostic factor analysis classified using $D_{\text{LCO}}$ and $\text{FEV}_1$

When classified through $D_{\text{LCO}}$, the $D_{\text{LCO}}$ impaired group showed a poor prognosis in all four factors by univariate analysis (Fig. 2). When classified through $\text{FEV}_1$, the $\text{FEV}_1$ impaired group showed a poor prognosis in three factors by univariate analysis (Fig. 3). However, there was no statistically significant mortality rate when classified as $\text{FEV}_1$ ($P$-value = 0.116) (Fig. 3B).

In multivariate analysis, when classified as $D_{\text{LCO}}$, all three factors showed significant prognostic differences. In severe AECOPD, $D_{\text{LCO}}$ has been shown to predict mortality rate, ventilator, and ICU
possibilities. When classified as FEV$_1$, the experience of mechanical ventilation and ICU showed statistical significance. However, there was no significant difference in mortality rate ($P = 0.075$) (Table 2).

| Parameter                        | Univariate analysis | Multivariate analysis |
|----------------------------------|---------------------|-----------------------|
|                                  | $D_{LCO}$ Normal    | $D_{LCO}$ Impaired    | $P$-value | Odds ratio | 95% confidence interval | $P$-value |
|                                  | group $(D_{LCO} > 50$, n = 227) | group $(D_{LCO} \leq 50$, n = 115) |
| Mortality in hospital$^\ddag$    | 3 (1.3%)            | 8 (7.0%)              | 0.008     | 4.408      | 1.070-18.167            | 0.040     |
| Mechanical ventilation$^\ddag$   | 11 (4.8%)           | 19 (15.7%)            | 0.001     | 2.855      | 1.216-6.704             | 0.016     |
| Intensive care unit$^\ddag$      | 16 (7.0%)           | 23 (20.0%)            | < 0.001   | 2.685      | 1.290-5.590             | 0.008     |
|                                  | FEV$_1$ Normal      | FEV$_1$ Impaired      |           |           |                       |           |
|                                  | group $(FEV_1 > 50$, n = 173) | group $(FEV_1 \leq 50$, n = 169) |
| Mortality in hospital$^\ddag$    | 3 (1.7%)            | 8 (4.7%)              | 0.116     | 4.633      | 0.858-25.036            | 0.075     |
| Mechanical ventilation$^\ddagger$| 7 (4.0%)            | 22 (13.0%)            | 0.003     | 3.518      | 1.335-9.270             | 0.011     |
| Intensive care unit$^\ddagger$   | 9 (5.2%)            | 30 (17.8%)            | < 0.001   | 4.527      | 1.886-10.869            | 0.001     |

$^\dagger$Numbers are presented as mean ± standard deviation

$^\ddagger$Numbers are presented as n (%)

Multivariate analysis was conducted for variables with a $P$-value of less than 0.05 in the univariate analysis, except for baseline spirometry.

Abbreviations: AECOPD, acute exacerbations of chronic obstructive pulmonary disease; FEV$_1$, forced expiratory volume in one second; $D_{LCO}$, diffusing capacity of the lung for carbon monoxide

**Correlation analysis between spirometer factors and length of hospital stay**
The length of hospital stay of the D\textsubscript{LCO} normal group was 7.3 ± 5.0 days and the D\textsubscript{LCO} impaired group was 12.4 ± 13.2 days. The length of hospital stay of the FEV\textsubscript{1} normal group was 7.7 ± 5.4 days and the FEV\textsubscript{1} impaired group was 10.4 ± 11.4 days. In the Pearson correlation analysis, both D\textsubscript{LCO} and FEV\textsubscript{1} showed a negative correlation. The correlation coefficient was more pronounced in the D\textsubscript{LCO} analysis. In multivariate linear regression analysis, both D\textsubscript{LCO} and FEV\textsubscript{1} showed a negative correlation. Additionally, the regression coefficient was more pronounced in the D\textsubscript{LCO} analysis (Table 3).

### Table 3
Correlation analysis of length of hospital stay

| Group                  | Number of events | Length of hospital stay (days)\textsuperscript{†} | Correlation coefficient | P-value | B     | P-value |
|-----------------------|------------------|-----------------------------------------------|-------------------------|---------|-------|---------|
| D\textsubscript{LCO} Normal group (D\textsubscript{LCO} > 50) | 227              | 7.3 ± 5.0                                    | -0.112                  | < 0.001 | -0.103 | < 0.001 |
| D\textsubscript{LCO} Impaired group (D\textsubscript{LCO} ≤ 50) | 115              | 12.4 ± 13.2                                  |                         |         |       |         |
| FEV\textsubscript{1} Normal group (FEV\textsubscript{1} > 50) | 173              | 7.7 ± 5.4                                    | -0.082                  | 0.001   | -0.075 | 0.007   |
| FEV\textsubscript{1} Impaired group (FEV\textsubscript{1} ≤ 50) | 169              | 10.4 ± 11.4                                  |                         |         |       |         |

\textsuperscript{†}Numbers are presented as mean ± standard deviation.

Multivariate analysis was conducted for variables with a P-value of less than 0.05 in the univariate analysis, except for baseline spirometry.

\(B\) is the regression coefficient, and the negative sign of the regression coefficient means that the variables are negatively associated.

**Abbreviations:** FEV\textsubscript{1}, forced expiratory volume in one second; D\textsubscript{LCO}, diffusing capacity of the lung for carbon monoxide

### ROC curve analysis of D\textsubscript{LCO} and FEV\textsubscript{1}

When analyzing the sensitivity and specificity using the ROC curve, D\textsubscript{LCO} showed better predictive ability than FEV\textsubscript{1} (Table 4). When analyzing three prognostic factors (mortality in hospital, mechanical ventilation, and ICU care) through ROC curve analysis, area under the curve (AUC) was greater than 0.68 in all cases of D\textsubscript{LCO} (Fig. 4). In contrast, the AUCs of FEV\textsubscript{1} were below 0.68 in all three prognostic factors. In addition, the sensitivity and specificity of D\textsubscript{LCO} were more than 64.1%, which was generally higher than FEV\textsubscript{1}. 

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Table 4
ROC curve analysis of $D_{LCO}$ and FEV$_1$

| Parameter                  | Prognostic factor | Optimal cut-off | Sensitivity | Specificity | AUC  | P-value |
|----------------------------|-------------------|-----------------|-------------|-------------|------|---------|
| Mortality in hospital      | $D_{LCO}$         | 48.5            | 71.0        | 72.7        | 0.827| < 0.001 |
| Mortality in hospital      | FEV$_1$           | 45.5            | 63.1        | 63.6        | 0.621| 0.173   |
| Mechanical ventilation     | $D_{LCO}$         | 51.5            | 68.4        | 65.5        | 0.717| < 0.001 |
| Mechanical ventilation     | FEV$_1$           | 44.5            | 66.5        | 65.5        | 0.675| 0.002   |
| Intensive care unit        | $D_{LCO}$         | 53.5            | 65.0        | 64.1        | 0.682| < 0.001 |
| Intensive care unit        | FEV$_1$           | 46.5            | 63.0        | 64.1        | 0.652| 0.002   |

Abbreviations: ROC, receiver operating characteristics; AUC, area under the curve; FEV$_1$, forced expiratory volume in one second; $D_{LCO}$, diffusing capacity of the lung for carbon monoxide.

Discussion

This is the first study to compare FEV$_1$ and $D_{LCO}$ as prognostic markers in severe patients with AECOPD in Korea. In our study, the factors of prognosis were defined as the length of hospital stay, mortality rate in the hospital, experience of ventilation, and experience of ICU care. Classification by $D_{LCO}$ showed significant differences in all prognostic factors. Classification by FEV$_1$ did not show a statistically significant mortality rate. In the correlation analysis, both $D_{LCO}$ and FEV$_1$ showed a negative correlation with the length of hospital stay. The correlation coefficient was more pronounced in the $D_{LCO}$ classification. In addition, when analyzing the ROC curve, $D_{LCO}$ showed better predictive ability than FEV$_1$. Of course, some odds ratio values were better when classified as FEV$_1$ in our study. However, $D_{LCO}$ was better in various analysis methods (correlation analysis, ROC curve analysis), which was likely to be as good as or better than FEV$_1$.

The PFT has various parameters. In general, we used FEV$_1$ to grade COPD and select the inhaler. In addition to FEV$_1$, $D_{LCO}$ is an important prognostic factor. In a study of smokers who did not show an obstruction pattern in PFT, a low $D_{LCO}$ group showed quickly decreased pulmonary function and COPD progression. Studies have shown that $D_{LCO}$ is a more accurate prognostic factor than FEV$_1$ when assessing postoperative risk. In addition, $D_{LCO}$ is known to accurately represent the actual emphysema level and performance status. These results suggest that $D_{LCO}$ can be a good predictor of early pulmonary dysfunction and prognosis.
If we know the prognosis of the patient early, we can focus on high-risk patients and improve the prognosis. The prognostic factors that can be used in the clinic are laboratory findings, scoring systems such as CAT or mMRC, and baseline spirometry. In some studies, high-C-reactive protein, eosinopenia, and thrombocytopenia are associated with poor outcomes in AECOPD. Although various scoring systems—such as St. George's Respiratory Questionnaire, mMRC, and CAT, are useful—patients with severe symptoms may not be graded or might have similar scores, making them difficult to use. Instead, we focused on baseline spirometry and confirmed that $D_{LCO}$ is more accurate in evaluating the prognosis of hospitalized patients than $FEV_1$. If a grading system that considers both $D_{LCO}$ and $FEV_1$ is developed, the prognosis can be predicted more accurately.

Our study was limited because it was a retrospective single-center study. In addition, the treatment received during the hospitalization period and the prognosis after discharge were not evaluated. Large prospective clinical studies that include information on treatment during hospitalization and postdischarge may be required.

**Conclusion**

$D_{LCO}$ was likely to be as good as or better as a prognostic marker than $FEV_1$ in severe AECOPD. Accurate classification using $D_{LCO}$ can help to shorten hospital stay, reduce ICU experience, and improve prognosis.

**Abbreviations**

COPD: Chronic obstructive pulmonary disease

AECOPD: Acute exacerbation of chronic obstructive pulmonary disease

$D_{LCO}$: Diffusing capacity of the lung for carbon monoxide

$FEV_1$: Forced expiratory volume in one second

**Declarations**

**Ethics approval and consent to participate**

This study was approved by the Guro Institutional Review Board. (KUGH16131-002).

**Consent for publication**

The requirement for informed consent from the patients was waived due to the retrospective nature of this study.

**Availability of data and materials**
Competing interests

There is no competing interest

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