

# Effectiveness of Nationwide COPD Pay-for-Performance Program on COPD Exacerbations in Taiwan

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**Background:** Chronic obstructive pulmonary disease (COPD) is a leading cause of morbidity and mortality worldwide. It has also imposed a substantial economic and social burden on the health care system. In Taiwan, a nationwide COPD pay-for-performance (P4P) program was designed to improve the quality of COPD-related care by introducing financial incentives for health care providers and employing a multidisciplinary team to deliver guideline-based, integrated care for patients with COPD, reducing adverse outcomes, especially COPD exacerbation. However, the results of a survey of the effectiveness of the pay-for-performance program in COPD management were inconclusive. To address this knowledge gap, this study evaluated the effectiveness of the COPD P4P program in Taiwan.

**Methods:** This retrospective cohort study used data from Taiwan's National Health Insurance claims database and nationwide COPD P4P enrollment program records from June 2016 to December 2018. Patients with COPD were classified into P4P and non-P4P groups. Patients in the P4P group were matched at a ratio of 1:1 based on age, gender, region, accreditation level, Charlson Comorbidity Index (CCI), and inhaled medication prescription type to create the non-P4P group. A difference-in-difference analysis was used to evaluate the influence of the P4P program on the likelihood of COPD exacerbation, namely COPD-related emergency department (ED) visit, intensive care unit (ICU) admission, or hospitalization.

**Results:** The final sample of 14,288 patients comprised 7144 in each of the P4P and non-P4P groups. The prevalence of COPD-related ED visits, ICU admissions, and hospitalizations was higher in the P4P group than in the non-P4P group 1 year before enrollment. After enrollment, the P4P group exhibited a greater decrease in the prevalence of COPD-related ED visits and hospitalizations than the non-P4P group (ED visit:  $-2.98\%$ ,  $p < 0.05$ , 95% confidence interval [CI]:  $-0.277$  to  $-0.086$ ; hospitalization:  $-1.62\%$ ,  $p < 0.05$ , 95% CI:  $-0.232$  to  $-0.020$ ), whereas no significant difference was observed between the groups in terms of the changes in the prevalence of COPD-related ICU admissions.

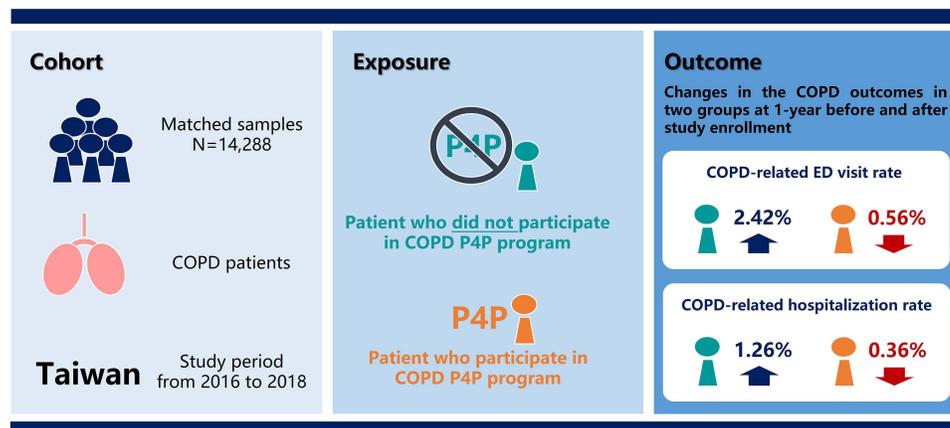
**Conclusion:** The COPD P4P program exerted a positive net effect on reducing the likelihood of COPD exacerbation, namely COPD-related ED visits and hospitalizations. Future studies should examine the long-term cost-effectiveness of the COPD P4P program.

**Keywords:** COPD, pay-for-performance program, guideline-based, comprehensive care, exacerbation, financial incentive

## Introduction

Chronic obstructive pulmonary disease (COPD) is a leading cause of morbidity and mortality worldwide. It has also imposed a substantial economic and social burden on the health care system.<sup>1,2</sup> In Taiwan, the estimated prevalence of COPD in 2015 was 6.1%

## Graphical Abstract



among adults 40 years or older.<sup>3</sup> COPD is the seventh most common cause of death in Taiwan.<sup>4,5</sup> The World Health Organization estimated that COPD will become the third leading cause of death worldwide by 2030.<sup>6</sup>

Acute exacerbations of COPD (AECOPD) are characterized by the worsening of respiratory symptoms that affects patients' health status, causing disease progression and increased frequency of emergency department (ED) visits and hospitalizations.<sup>7</sup> COPD exacerbation accounts for the greatest share of the overall COPD-related economic burden, driving the substantial expenditure of health care resources.<sup>7-10</sup> In Taiwan, hospitalization due to AECOPD is the major contributor to COPD-related medical expenses, and the mortality rate 1 year after initial hospital discharge after COPD exacerbation is 22%.<sup>9,11</sup> Moreover, the Epidemiology and Impact of COPD (EPIC) reported that among 207 patients with COPD in Taiwan, 59% had unscheduled doctor or clinic visits.<sup>12</sup> These data highlight the importance of using the latest evidence to minimize AECOPD, reducing future risks such as preventable hospitalization. Guidelines facilitate the incorporation of research evidence into clinical practice and support clinicians in their decisions pertaining to patient care.<sup>13,14</sup> In 2017, the first version of Taiwan COPD guidelines was developed by the Health Promotion Administration and the Taiwan Society of Pulmonary and Critical Care Medicine (TSPCCM) by using the Grading of Recommendations Assessment, Development and Evaluation approach, which facilitates change in clinical practices through sound evidence-

based reporting. However, health care providers' use of and adherence to these guidelines in clinical practice remain unsatisfactory.<sup>15-17</sup> Studies have demonstrated varying levels of adherence to evidence-based guidelines in the management of COPD.<sup>16-19</sup>

Pay for performance (P4P), also known as "value-based purchasing," is a strategy to enhance the translation of evidence into practice and to promote the change in the behavior of health care providers to align financial incentives with improvement in health care quality and cost containment.<sup>20-22</sup> In Taiwan, the National Health Insurance Administration (NHIA) has introduced P4P programs for pulmonary tuberculosis, asthma, diabetes, end-stage renal disease (ESRD), and breast cancer since 2001.<sup>23-30</sup> Several studies have evaluated the effect of these P4P programs on health care quality and expenditure.<sup>26-29</sup> The COPD P4P program, which was initiated in 2017, aims to improve the quality of COPD treatment and decrease COPD exacerbation by introducing financial incentives and improving health care providers' adherence to guidelines. This program offers bonus payments to healthcare providers and its high-quality performance has been demonstrated according to quality indicators established by the Taiwan National Health Insurance Administration (NHIA).

This study examined the effect of the Taiwan NHIA's COPD P4P program on COPD exacerbation events. We compared the differences between patients with COPD enrolled into the P4P program and those who were not enrolled in the program in terms of the prevalence of COPD-related emergency visits, intensive care unit (ICU) admissions, and hospitalizations.

## Materials and Methods

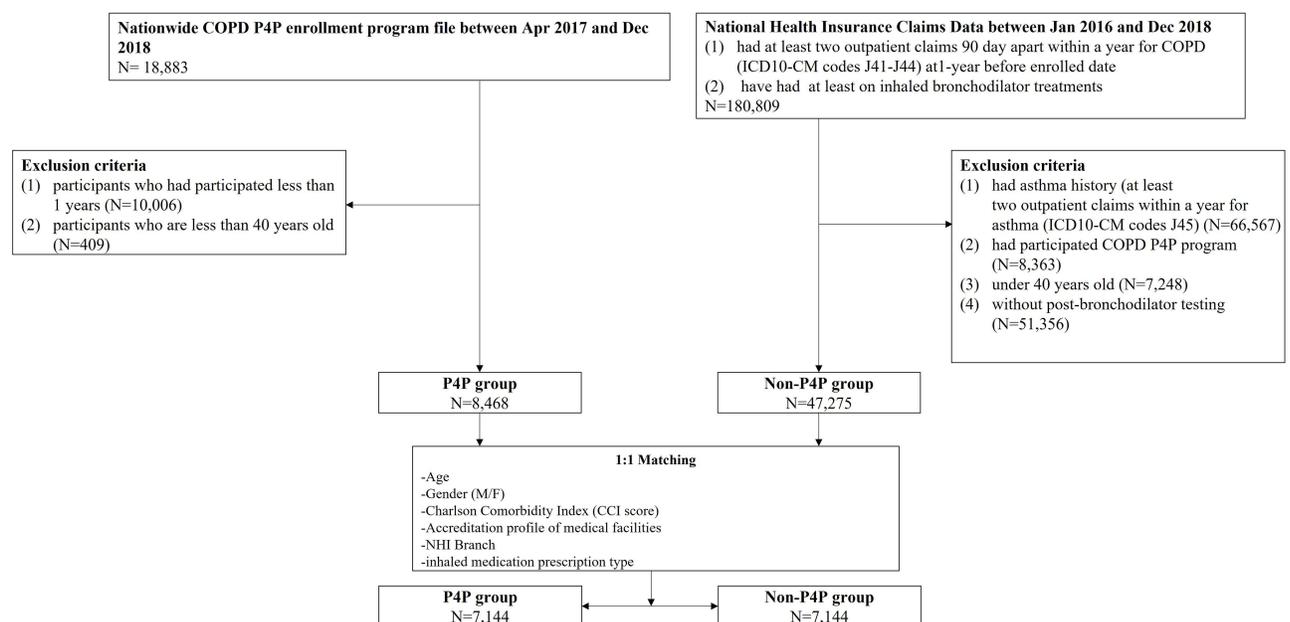
### Data Sources

We conducted this retrospective study using 2 Taiwanese nationwide population-based databases. One database was the nationwide COPD P4P enrollment program file from April 2017 through December 2018; this allowed the precise identification of whether patients were enrolled into P4P program. The other database was the National Health Insurance claims database from January 2016 through Dec 2018, from which we obtained patient information comprising demographics, outpatient visits, hospital admissions, ED visits, patient comorbid conditions, diagnostic codes based on the ICD10 Clinical Modification (ICD10-CM), drug prescriptions, procedure codes, and health provider characteristics. The present study was approved by the Institutional Review Board of Changhua Christian Hospital (approval number: 190910). Written informed consent was not required because of the retrospective nature of the investigation. The database accessed has deidentified data. Researchers were followed the Computer-Processed Personal Data Protection Law and privacy regulations in Taiwan.

### Study Population and Sample Selection

Patients were classified into either a P4P or non-P4P group based on the enrollment into the COPD P4P program (Figure 1). We allocated patients to one of these groups

by using the nationwide COPD P4P enrollment program file to determine their COPD P4P program involvement. The date of an initial enrollment (NHI claim code: P6011C) record was set as the index date for individual patients in the P4P group. Patients who participated in the program for less than 1 year or who were aged less than 40 years were excluded from the present study. Patients with COPD who were not enrolled into the P4P program (non-P4P group) were identified from the NHI administrative claims database; we initially included patients 40 years or older and diagnosis of COPD (ICD-10-CM code J41-J44) at least two outpatient visits within the 90-day period due to the validity of refill prescription is 90 days based on the policy of National Health Insurance in Taiwan. Patients were excluded from the non-P4P group for the following reasons: they 1) patients who had participated Taiwan's asthma pay-for-performance program (NHI claim code: P1612C, P1614B, P1615C, P1612C), (2) had participated in the COPD P4P program (had NHI claim code: P6011C, P6012C, P6013C, P6014C), and (3) had not completed postbronchodilator testing (NHI claim code: 17003C, 17004B, 17006B, 17007B, 17019C) during the study period. To accountably address the problem of patients with multiple outpatient visits to different hospitals or providers, we associated such non-P4P patients with their most frequently seen physician, which we determined based on the highest number of care visits during the study period.<sup>31,32</sup> In total, 8468 P4P patients and 47,275 non-



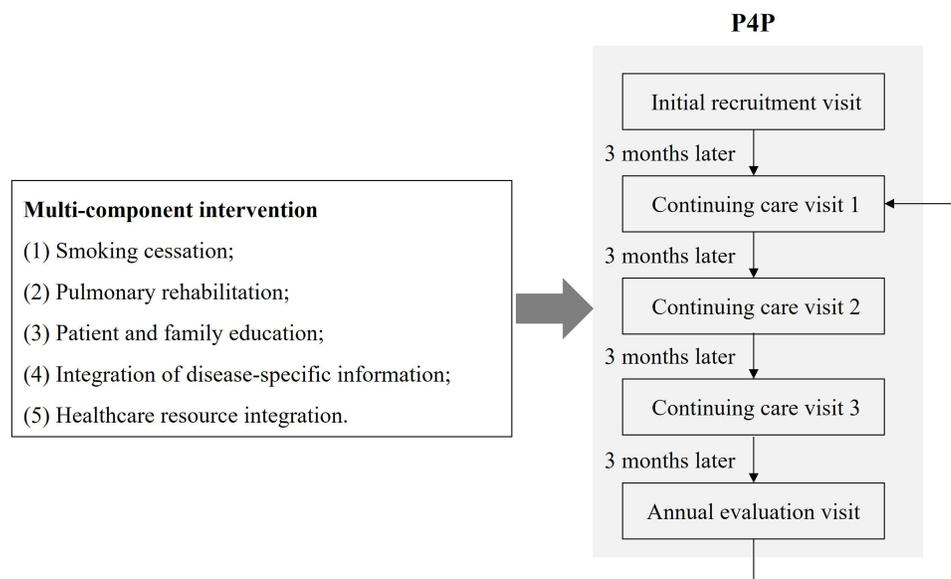
**Figure 1** Flowchart of participant selection for patients with COPD in the P4P and non-P4P groups.

P4P patients were considered. Approximately 15.2% of patients with COPD in Taiwan were enrolled into the P4P program.

## COPD P4P Program

The COPD P4P program was initiated on April 1, 2017. A medical institution, divided into 1<sup>st</sup> tier hospital (secondary and tertiary care) and 2<sup>nd</sup> tier hospital (primary care), could be approved as a health care provider in this program and can voluntarily join this program if they met one of the following conditions: (1) first-tier hospital staffed by at least 3 pulmonary specialists, 1 respiratory therapist, and 1 case manager and (2) second-tier hospital staffed by at least 1 otorhinolaryngologist or pediatric specialist or family medicine specialists. The P4P multi-disciplinary team (MDT) included pulmonary specialists, otorhinolaryngologists, pediatric specialists, family medicine specialists, respiratory therapists, pharmacists, and case managers, all of whom had obtained professional COPD training provided and certified by TSPCCM. Under the COPD P4P program guidelines, these certified physicians or specialists could then enroll patients individually into the program. The COPD P4P program included patients identified using International Classification of Diseases, 10th edition (ICD10; codes J41-J44) diagnosis codes, and their diagnosis was confirmed using a spirometer (postbronchodilator FEV1/FVC < 70%)

during a 90-day period on an outpatient basis in the given health care organization. Once enrolled, patients were recommended to maintain regular follow-up every 3 months with the same physician at the same medical site (Figure 2). Patients who met the inclusion criteria were enrolled into P4P and received comprehensive pharmacologic and nonpharmacologic treatment according to Taiwan's COPD guidelines. The nonpharmacologic intervention comprised (1) smoking cessation, (2) pulmonary rehabilitation (PR), (3) patient and family education, (4) integration of disease-specific information, and (5) health care resource integration. Physicians assessed the enrolled patients and adjusted their medications and managed their COPD treatment. Case managers provided every patient with an individualized education program that integrated all key disease-specific information. The respiratory therapist instructed the patient on an individualized physical training program to perform at home or a short course of outpatient-based PR. In addition, a two-way referral system between hospitals and clinics was developed and is applied in this program. Patients with stable COPD were provided with a referral from first- to second-tier hospitals, whereas patients experiencing exacerbated symptoms were referred from second- to first-tier hospitals. Four process- and outcome-based quality indicators were designed as components of financial incentives for health care providers. The quality indicators for process-based performance



**Figure 2** Flowchart of the pay-for-performance (P4P) program for COPD. Once enrolled into P4P program at the initial enrollment visit, the P4P patient visited a physician once each quarter, completing 3 regular care visits and 1 annual evaluation visit. Multicomponent intervention for P4P was governed by Taiwan COPD guideline recommendations, which considered: (1) smoking cessation, (2) pulmonary rehabilitation, (3) patient and family education, (4) integration of disease-specific information, and (5) health care resource integration.

comprised rates of follow-up visit, 6-month smoking cessation, PR, and medication adherence. The quality indicators for outcome-based performance included rates of 14-day readmission, ED visit, and ICU admission.

## Matching Data

To minimize selection bias due to the lack of random assignment for patients in the COPD P4P program, we matched patients enrolled into the P4P program with non-P4P patients at a 1:1 ratio by age, sex, hospital accreditation level, NHI branch, comorbidity score, and inhaled medications. The comorbidity score was calculated using the Charlson comorbidity index (CCI), which was determined from patients' NHIA claims data. The final study population after matching of 14,288 eligible patients included 7144 (50%) in the P4P group and 7144 (50%) in the non-P4P group. Given that non-P4P patients lacked actual P4P enrollment index dates, the P4P initial enrollment dates of the matched P4P counterparts were used as those for non-P4P patients.

## Outcome Measure

The 3 clinical outcomes related to COPD exacerbation in this study were COPD-related ED visit, COPD-related hospitalization, and COPD-related ICU admission 1 year before and after initial P4P enrollment. COPD-related ED visit, COPD-related hospitalization, and COPD-related ICU admission were determined by primary contact diagnosis. One-month duration between admissions was counted as a new episode. The medication adherence was calculated as medication possession ratio (MPR) as quality indicators for process-based performance to evaluate the process outcome.

## Sensitivity Analysis

We conducted sensitivity analyses to assess the robustness of the study results. Because pharmacological treatment (according to guideline recommendations) was a part of the P4P program, which may have affected patient outcomes, we created a second comparison subgroup (non-P4P group) in the study by removing inhaled bronchodilator treatments from the matching variables and reanalyzing the effectiveness of COPD P4P program through difference-in-difference (DID) estimation. Moreover, we conducted an adjusted DID model controlled for exacerbations (COPD-related ED visit and COPD-related hospitalization) in the year before baseline.

## Statistical Analysis

Data are expressed as frequencies with percentages and means  $\pm$  standard deviations for categorical and continuous variables, respectively. The distributions of variables between the P4P and non-P4P groups before matching were compared using the Student's *t* test and chi-square test. After matching, the paired samples *t* test and McNemar test were used. This study used a DID model to compare the outcomes between the 2 groups before and after the implementation of the P4P program. We compared the prevalence of COPD-related ED visits, ICU admissions, and hospitalizations between the 2 groups at 1 year before and after study enrollment. Generalized estimating equations were applied to account for repeated observations of intraclass correlation between the same patients and patients within the same matched pairs.<sup>33</sup> Analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). In all analyses, 2-tailed *P* values of  $<0.05$  were considered statistically significant.

## Patient and Public Involvement Statement

As this was a retrospective study, patients were not involved in the recruitment and conduct of the present study.

## Result

### Characteristics of the Study Population

During the participant selection process (Figure 1), a total of 55,743 eligible patients were enrolled for subsequent analysis, namely 47,275 patients in the non-P4P group and 8468 patients in the P4P group. The baseline characteristics for the 2 groups before and after the matching process are detailed in Table 1. Before matching, the mean age was  $70.63 \pm 11.31$  years in the non-P4P group and  $71.5 \pm 9.92$  years in the P4P group ( $P < 0.0001$ ). Male participants were predominant in our study population. Compared with the non-P4P group, the P4P group had lower CCI scores, lower use of a single inhaler (SAMA, SABA, LAMA, or LABA), and higher use of dual-inhaler combination therapy. After the 1:1 patient matching process, 7144 participants were assigned to each group. The differences between the 2 groups in terms of all participant characteristics were nonsignificant (standardized difference  $<0.1$  for each covariate).

### COPD Outcomes at 1 Year Before P4P Enrollment

Among the 3 clinical outcomes related to COPD exacerbation shown in Figure 3, the P4P group had

**Table 1** Characteristics of Patients with COPD for Unmatched and Matched Samples

| Characteristics   | Before Matching          |                    |            | After Matching         |                    |
|---|--------------------------|--------------------|------------|------------------------|--------------------|
|   | Non-P4P Group (N=47,275) | P4P Group (N=8468) | p-value    | Non-P4P Group (N=7144) | P4P Group (N=7144) |
| <b>Age (Mean ± SD)</b>  | 70.63±11.31              | 71.5±9.92          | <0.0001    | 71.58±9.49             | 71.58±9.49         |
| <b>Gender (N, %)</b>  |                          |                    |            |                        |                    |
| Female  | 8071 (17.1%)             | 705 (8.3%)         | <0.0001    | 389 (5.4%)             | 389 (5.4%)         |
| Male  | 39,204 (82.9%)           | 7763 (91.7%)       |            | 6755 (94.6%)           | 6755 (94.6%)       |
| <b>Branch (N, %)</b>  |                          |                    | <0.0001    |                        |                    |
| Taipei  | 14,384 (30.4%)           | 2169 (25.6%)       |            | 2017 (28.2%)           | 2017 (28.2%)       |
| Northern  | 6586 (13.9%)             | 1057 (12.5%)       |            | 814 (11.4%)            | 814 (11.4%)        |
| Central   | 9970 (21.1%)             | 2874 (33.9%)       |            | 2431 (34%)             | 2431 (34%)         |
| Southern  | 8179 (17.3%)             | 965 (11.4%)        |            | 850 (11.9%)            | 850 (11.9%)        |
| Kao-Ping  | 7196 (15.2%)             | 1100 (13.0%)       |            | 945 (13.2%)            | 945 (13.2%)        |
| Eastern   | 960 (2.0%)               | 303 (3.6%)         | 87 (1.2%)  | 87 (1.2%)              |                    |
| <b>Accreditation level (N, %)</b>   |                          |                    | <0.0001    |                        |                    |
| Medical center  | 11,847 (25.1%)           | 2356 (27.8%)       |            | 1923 (26.9%)           | 1923 (26.9%)       |
| Regional hospital   | 16,691 (35.3%)           | 3972 (46.9%)       |            | 3506 (49.1%)           | 3506 (49.1%)       |
| District hospital   | 7643 (16.2%)             | 1543 (18.2%)       |            | 1261 (17.7%)           | 1261 (17.7%)       |
| Clinics   | 11,094 (23.5%)           | 597 (7.1%)         | 454 (6.4%) | 454 (6.4%)             |                    |
| <b>CCI (Mean ± SD)</b>  | 2.89±1.9                 | 2.66±1.74          | <0.0001    | 2.48±1.56              | 2.48±1.56          |
| <b>Pattern of inhaled medication prescription*<br/>By regimen, (N, %)</b>   |                          |                    | <0.0001    |                        |                    |
| Short-acting bronchodilators alone  | 5164 (10.92%)            | 126 (1.49%)        |            | 77 (1.1%)              | 77 (1.1%)          |
| Long-acting bronchodilators alone   | 10,368 (21.93%)          | 1167 (13.78%)      |            | 821 (11.5%)            | 821 (11.5%)        |
| Long-acting bronchodilators in combination (including ICS/LABA) or Dual bronchodilators or Triple bronchodilators | 31,743 (67.15%)          | 7175 (84.73%)      |            | 6246 (87.4%)           | 6246 (87.4%)       |

**Notes:** P-value for comparison of patient demographic and clinical characteristics between P4P and non-P4P patients. \*At least one bronchodilator prescribed during the follow-up period.

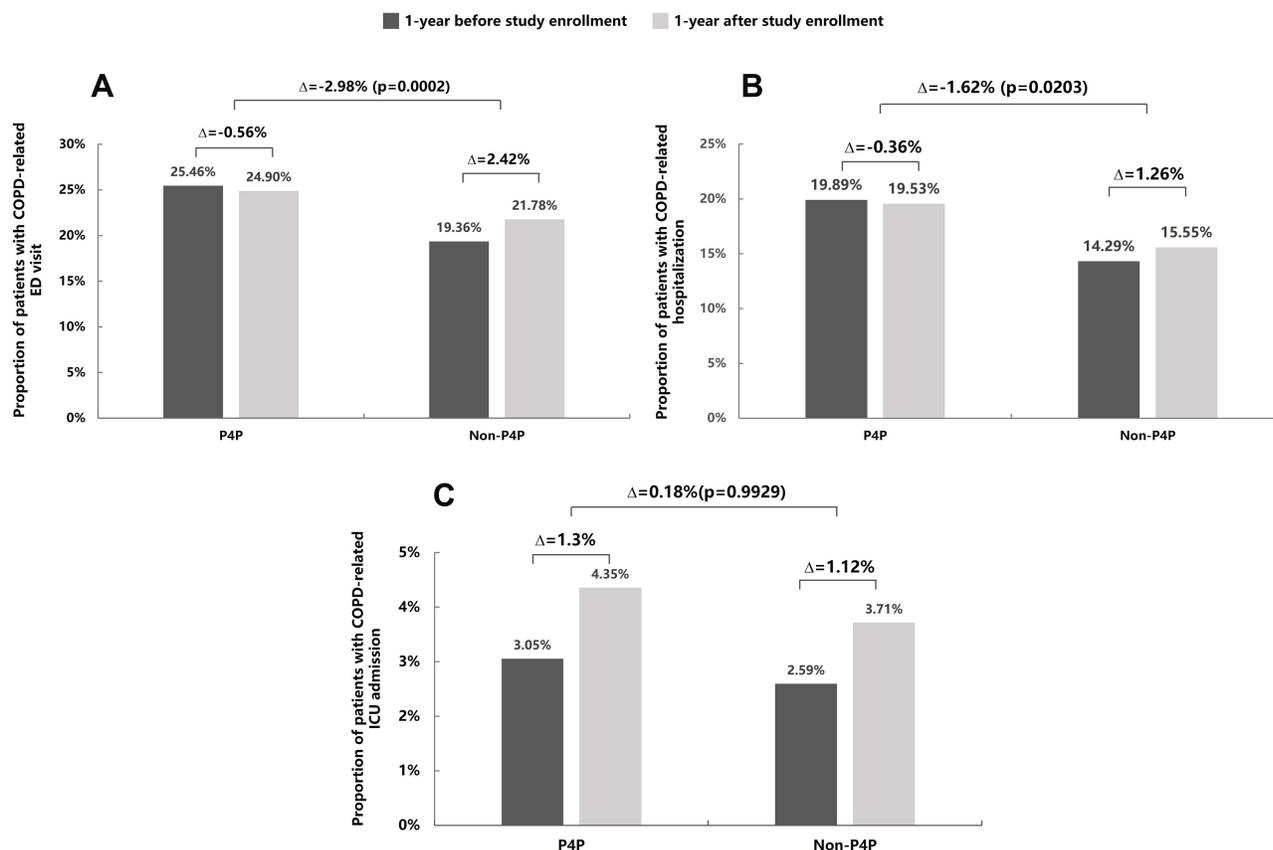
**Abbreviation:** CCI, Charlson Comorbidity Index.

a significantly higher prevalence of COPD-related ED visits than the non-P4P group within the year preceding their P4P enrollment (25.5% vs 19.4%,  $P < 0.0001$ ). Although the P4P group also had a higher prevalence of COPD-related hospitalizations and ICU admissions than their counterparts prior to P4P enrollment, the differences were not statistically significant (19.9% vs 14.3%,  $P = 0.0551$  and 3.1% vs 2.6%,  $P = 0.0934$ ).

## Changes in the COPD Outcomes Between 1 Year Before and 1 Year After P4P Enrollment

The changes in the COPD exacerbation event before and after study enrollment between the P4P and non-P4P groups are shown in Figure 3. COPD-related ED visits

were more prevalent in the P4P group than in the non-P4P group at 1 year before P4P enrollment. At 1 year after study enrollment, the COPD-related ED visits became more prevalent in the non-P4P group (from 19.36% to 21.78%,  $P < 0.0001$ ), whereas they became significantly less prevalent in the P4P group (from 25.46% to 24.9%,  $P < 0.0001$ ). Thus, the P4P program exerted a significantly negative net effect (0.56% decrease vs 2.42% increase;  $P < 0.005$ ) on the prevalence of COPD-related ED visits (Figure 3A). Similarly, although the prevalence of COPD-related hospitalization increased in the non-P4P group (from 14.29% to 15.55%,  $P < 0.0001$ ), the P4P group exhibited a significant decrease (from 19.89% to 19.53%,  $P < 0.0001$ ). The P4P group demonstrated a 1.62% greater improvement compared with the non-P4P group (0.36% decrease vs 1.26 increase;  $P=0.020$ ) (Figure 3B); this



**Figure 3** Changes in COPD-related ED visit, hospitalization, and ICU admission in non-P4P group and P4P group at 1-year before and after study enrollment. (A) COPD-related ED visit; (B) COPD-related hospitalization; (C) COPD-related ICU admission.

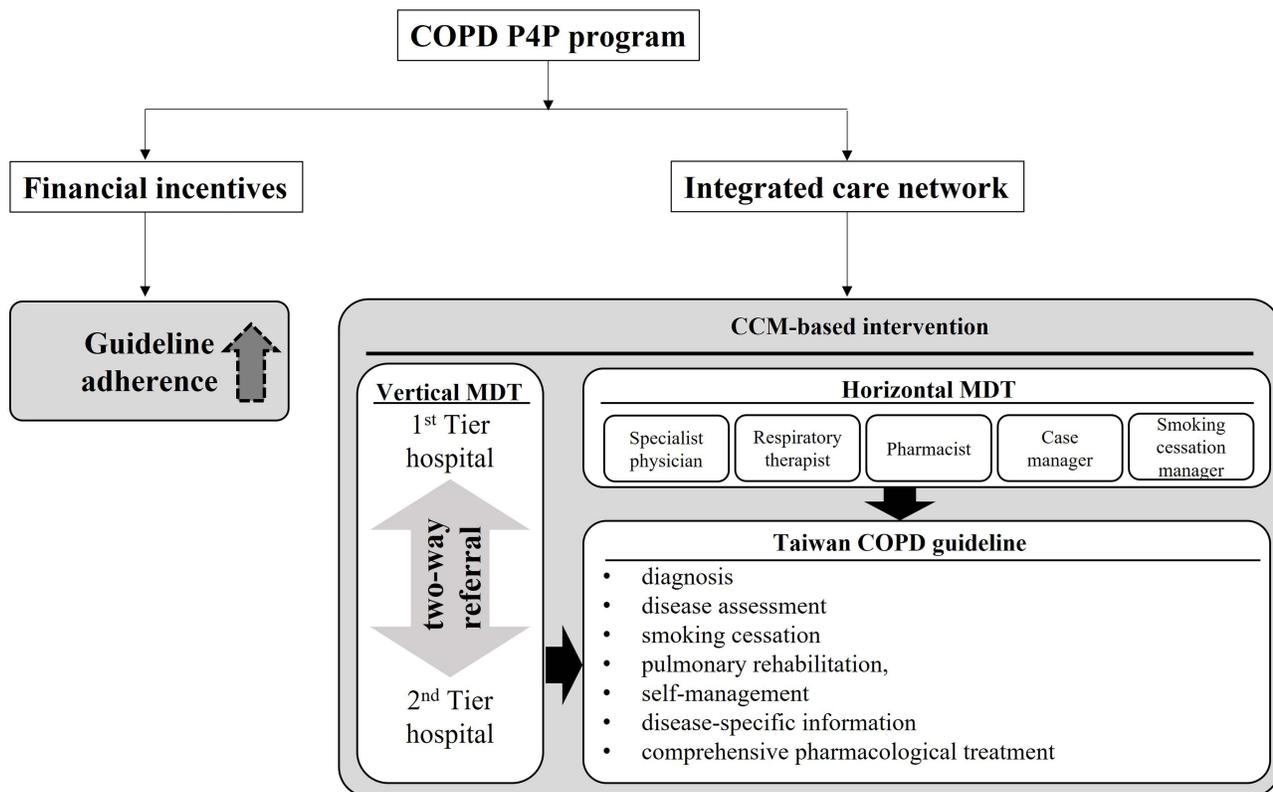
suggested a significantly negative effect of the P4P program on the adverse outcome of hospitalization. By contrast, the prevalence of ICU admissions (1.3% increase vs 1.12% increase;  $P < 0.05$ ) increased in both groups after P4P enrollment, with no significant difference observed

between the P4P and non-P4P groups (Figure 3C). An analysis of DID with GEE model showed that the effect of the COPD P4P program on COPD-related ED visit and COPD-related hospitalization was significant (Table 2). Moreover, the result of quality indicators for process-

**Table 2** Number of Patients and Prevalence of the Outcome Variables (COPD-Related ED Visits, COPD-Related Hospitalizations, and COPD-Related ICU Admissions). And the DID Analysis Results for the Effects of the COPD P4P Program with GEE Model

| Indicator              | I-Year Before Study Enrollment<br>N (%) | I-Year After Study Enrollment<br>N (%) | $\beta$ (SE)   | p-value | 95% CI           |
|------------------------|---|--|----------------|---------|------------------|
| <b>ED visit</b>        |   |  |                |         |                  |
| P4P                    | 1819 (25.46%)                           | 1779 (24.90%)                          | -0.181 (0.049) | <0.001  | -0.277 to -0.086 |
| Non-P4P                | 1383 (19.36%)                           | 1556 (21.78%)                          |                |         |                  |
| <b>Hospitalization</b> |   |  |                |         |                  |
| P4P                    | 1421 (19.89%)                           | 1395 (19.53%)                          | -0.126 (0.054) | 0.020   | -0.232 to -0.020 |
| Non-P4P                | 1021 (14.29%)                           | 1111 (15.55%)                          |                |         |                  |
| <b>ICU admission</b>   |   |  |                |         |                  |
| P4P                    | 218 (3.05%)                             | 311 (4.35%)                            | -0.001 (0.123) | 0.986   | -0.242 to 0.200  |
| Non-P4P                | 185 (2.59%)                             | 265 (3.71%)                            |                |         |                  |

**Abbreviations:** COPD, Chronic Obstructive Pulmonary Disease; DID, difference-in-difference; ED, Emergency department; GEE, generalized estimating equation; ICU, Intensive care unit; P4P, pay-for-performance; SE, standard error; 95% CI, 95% confidence interval.



**Figure 4** Possible mechanism underlying the effectiveness of COPD P4P program. Financial incentives encourage physicians to change their behavior and improve guideline adherence, and an integrated care network is established by two types of MDT (vertical MDT and horizontal MDT) in the COPD P4P program to achieve CCM-based intervention according to COPD guideline recommendations, thereby preventing COPD exacerbation.

based performance, medication adherence rate, demonstrate that the medication adherence rate is higher in P4P group compared with non-P4P group ([Supplemental Material Table 1](#)).

## Result of Sensitivity Analysis

In sensitivity analysis ([Supplemental Material Table 2](#)), the decreases in the prevalence of COPD-related ED visits and hospitalizations were greater in the P4P group than in the non-P4P group. The estimated net effect of the P4P program was similar to the results in the main analysis. In addition, we adjust for exacerbations history in the previous year, the result also agrees with the result of the main analysis ([Supplemental Material Table 3](#)). The sensitivity analysis indicates that those results are robust.

## Discussion

To the best of our knowledge, this is the first study to assess the effectiveness of comprehensive care in patients with COPD enrolled into a national guideline-based P4P program. Our findings demonstrated that the P4P group exhibited a greater decrease in the prevalence of COPD-related ED visits and

hospitalizations than the non-P4P group (ED visits: 0.56% decrease in the P4P group vs 2.42% increase in the non-P4P group; hospitalization: 0.36% decrease vs 1.26% increase). In terms of clinical outcomes, COPD P4P program reduces 3.4 COPD-related ED visit and 6.2 COPD-hospitalization per 1000 person-year, respectively. A previous study reported that the cost of every ED visit and hospitalization of a patient with COPD ranged from US\$244 to US\$1304 and from US\$ 805 to US\$7839, respectively, in Taiwan.<sup>9</sup> Although P4P implementation may increase the cost of COPD care because the care team requires case manager, respiratory therapist, and smoking cessation manager, our finding suggest that COPD P4P have beneficial effect on decrease COPD-related ED visit and COPD-hospitalization which may contribute to reduce the cost of ED visit and hospital for COPD in long term. Further research on the cost-effectiveness of the COPD P4P program is warranted.

Our study demonstrated that the COPD P4P program had positive net effects on health outcomes in patients with COPD. We suggest a possible mechanism explaining the effectiveness of the COPD P4P program in terms of the prevention of COPD exacerbation, namely COPD-related

ED visits and hospitalizations (Figure 4). This mechanism involves the program's chronic care model (CCM)-based intervention and associated guideline adherence pursued by an MDT. CCM is a framework devised to improve management, prevention of complications, and outcomes in patients with chronic diseases. It involves 6 interrelated components, namely the health system, coordinated health care or delivery system design, a decision support system to support physician guideline adherence, patient self-management, community resources, and a clinical information system.<sup>34,35</sup> The results of a systematic review demonstrated that patients with COPD who received interventions with 2 or more CCM components exhibited lower rates of hospitalizations and emergency visits and shorter lengths of hospital stays compared with controls.<sup>36</sup> In the current COPD P4P program, activities can be mapped onto all six CCM components as follows: (1) health system: the COPD P4P program; (2) coordinated health care or delivery system design: MDT; (3) decision support or expert system: Taiwan COPD guidelines and health care provider education; (4) patient self-management: integrated information provision, patient and family education, and provision of self-management tools; (5) community resources: the two-way referral system; and (6) clinical information system: the COPD P4P virtual private network as an information system for reporting patient clinical outcomes. Our findings indicate that the COPD P4P program integrates all 6 components of CCM, transferring them to clinical practice and aligning financial incentives with high-quality health care to generate a positive net effect on the reduction of COPD exacerbation events. Thus, these activities in the COPD P4P program being mappable to the 6 components of CCM is a possible explanation for the COPD P4P program's effectiveness. Therefore, the likelihood of preventing COPD exacerbation in patients with COPD who receive the COPD P4P program intervention is greater, in turn, reducing COPD-related ED visits and hospitalizations.

The COPD P4P program aims to improve guideline adherence, which is the main target of the program's financial incentives. Concordance between guideline recommendations and clinical practice is critical to ensure that the physician provides patients with appropriate management.<sup>37,38</sup> Studies have reported that GOLD guideline adherence leads a decrease in all COPD-related symptoms among patients, reduces health care costs and the number of all-cause inpatient hospitalizations and emergency department visits, and improves patient outcomes.<sup>39,40</sup> However, poor guideline

adherence has been noted in real-world COPD treatment centers, with several barriers impeding the adoption of guidelines in routine clinical practice.<sup>41,42</sup> In Taiwan, a nationwide telephone survey of the prevalence of COPD revealed that although up to 6.1% of the population may have COPD, less than 2% of the population have undergone spirometry examination. Moreover, other studies have reported that the pharmacological rate of concordance with GOLD was only 44.9% in 2017.<sup>3,38</sup> These findings suggest that adherence to the guidelines is unsatisfactory in Taiwan. P4P programs have become popular policies for increasing adherence to health care guidelines in many countries.<sup>43,44</sup> Empirical findings have also demonstrated that P4P programs in Taiwan have improved health outcomes in patients with diabetes, breast cancer, hepatitis B and C, and early chronic kidney disease; these improvements are associated with guideline adherence.<sup>23,25,27,29,30,45</sup> Taiwan's COPD P4P program requires health care providers to provide patient-centered comprehensive care according to the Taiwan COPD guidelines, with additional financial bonuses for those who achieve high-quality performance on the prescribed quality indicators. Although this incentive design may encourage physicians to modify their behaviors and improve guideline adherence, the incentives are presently too few to sufficiently cover all activities in the P4P program. Moreover, improvements in the physicians' guideline adherence might be explained by the financial incentives for individual effort and task performance, amplifying the reported effects of interventions and performance feedback reports.<sup>46</sup>

Patients with COPD are heterogeneous in terms of disease severity, presence of exacerbations and comorbidities, and social needs. This necessitates an MDT that is skilled, knowledgeable, and capable of implementing practical strategies according to national COPD guidelines. A study reported that the comprehensive, gold-standard care implemented by an integrated COPD MDT helped reduce emergency general practitioner visits (3.37–0.79 visits per patient,  $P < 0.001$ ) and exacerbation events (2.64–0.56 per patient,  $P = 0.01$ )<sup>47</sup> A retrospective study also showed that a MDT for COPD management significantly reduced hospital admissions and ED visits over each phase of the relevant study period.<sup>48</sup> Similarly, our findings demonstrated that the implementation of guideline-based comprehensive care with an MDT approach reduced the events of COPD exacerbation, namely the prevalence of COPD-related ED visits and hospitalizations. In the COPD P4P program, two MDTs, one horizontally and one vertically aligned, were conceived. The

horizontal MDT included specialists, respiratory therapists, pharmacists, and case managers that collaborated to offer patients diagnosis, disease assessment, and a variety of other services to suit patients' disease severity and needs (eg, smoking cessation, PR, self-management, and disease-specific information). The vertical MDT, involving first- and second-tier hospitals, offered a two-way referral to integrate health care resources; on the basis of their condition, patients were provided a referral to one of the two hospital types. In summary, the integrated health care network established by the two types of MDTs in the COPD P4P program model may provide patients with comprehensive care according to their condition, thereby preventing COPD exacerbation.

Comorbidities were observed in patients with and without COPD, but the trend was more prominent in patients with COPD.<sup>49</sup> Furthermore, having more comorbidities has been reported to be a critical independent risk factor for frequent AECOPD and hospitalization.<sup>50,51</sup> In our study, the mean CCI scores in the non-P4P and P4P groups were  $2.89 \pm 1.9$  and  $2.66 \pm 1.74$ , respectively, indicating that comorbidities are commonly reported in patients with COPD and are associated with an increased risk of AECOPD.<sup>52</sup> Comprehensive COPD management should integrate comorbidity profiles. A diabetes P4P program was identified as a P4P program having a greater positive impact on health outcomes in patients with multiple chronic conditions (MCCs).<sup>53</sup> Whether patients with COPD and MCCs would gain greater benefit from P4P initiatives should be further evaluated.

The accreditation level of hospitals and health care clinics was a key factor in COPD management that was examined in this study because this level can affect the quality of health care provided. For instance, the proportions of patients with inhaled bronchodilator prescriptions were 92.6% and 40.5% among patients of tertiary hospitals and private clinics, respectively.<sup>54</sup> Moreover, the numbers of general health care personnel, specialists of internal medicine, and pulmonology specialists might vary according to the accreditation level of a given hospital. In addition, structures may differ in different levels of healthcare provider characteristics, including hospital level and geographic location, may affect the capacities of individual health care institutions.<sup>55</sup> Therefore, in addition to age, sex, CCI (Charlson Comorbidity Index) score, and history of inhaled bronchodilator prescriptions, we adjusted for the accreditation level of hospitals and health care clinics to mitigate potential confounding factors.

In our study, a higher proportion of the P4P group exhibited dual or triple therapy prescription than the non-P4P group over the study period, and we observed that the prevalence of hospitalizations and ED visits significantly declined in the P4P group only at 1 year after P4P enrollments. Maintenance bronchodilator therapy with long-acting bronchodilators is the standard treatment for COPD.<sup>56</sup> A previous study demonstrated that long-acting bronchodilator-containing regimens reduce exacerbation risk and hospitalizations among patients with COPD.<sup>57</sup> Tsai et al reported that the increased use of LAMA and LABA/ICS may have reduced the average number of COPD-related hospital admissions in Taiwan from 2004 to 2010.<sup>58</sup> These studies provide a possible clue for the significant reduction in the prevalence of COPD-related ED visits and hospitalizations in the P4P group.

In Germany, a nationwide reward-based COPD management program achieved significant improvements in mortality, morbidity and process quality, but at higher costs.<sup>59</sup> In comparison with DMP, our findings demonstrate the beneficial effect of comprehensive care of COPD with financial incentive, which had greater decline in COPD-related emergency visit rate and COPD-related hospitalization rate in COPD P4P program in Taiwan. The reported differences, while statistically significant, do not appear clinically meaningful. However, our findings demonstrate that COPD P4P program reduces 3.4 COPD-related ED visit and 6.2 COPD-hospitalization per 1000 person-year which have the potential beneficial effect of improving the quality of care in COPD. Furthermore, previous studies evaluate the effectiveness of pay-for-performance program for diabetes care in Taiwan, DID analysis show that the more decline of diabetes-related ambulatory care-sensitive conditions (ACSCs) (the value of DID was  $-0.008$ ) and number of diabetes-related hospitalization in P4P group (the value of DID was  $-0.027$ ).<sup>28,60</sup> Our finding was consistent with the Taiwan DM P4P research, both these results demonstrate that the effectiveness of COPD P4P program is modest.

This study has some limitations. First, although we used a frequency-matching approach to determine comparable groups to avoid selection bias and confounding factors based on retrospective non-randomised study form. FEV1, smoking history, symptom burden, BMI, and the risk factor of exacerbation are unavailable in NHIRD, which limits the comparability between the P4P group and non-P4P group. As alternatives, we use age, inhale medication prescription type, and Charlson comorbidity index, which is a potential risk factor for exacerbation, as a comprehensive assessment. And

the reasons are as follows: (1) Older patients experienced a higher rate of acute exacerbation episodes of COPD; (2) Intensity of treatment depends upon the severity of the disease. So, we use inhaled medication prescription type (mono, dual, or triple therapy) as a comprehensive assessment of disease severity, which also reflects the probability of COPD exacerbations; (3) Comorbidities were associated with having frequent exacerbations and increased exacerbation risk of COPD. Second, the change in outcome variables might have been caused by other unobservable factors, such as smoking behavior or patients' medication adherence. To evaluate the effect of the COPD P4P program, the DID model was used in the present study. Fourth, the present study only demonstrated the short-term effect of the COPD P4P program. Therefore, further assessment of the long-term effects of this program is required. Finally, the study findings may not be generalizable to other study populations due to the unique health care system and COPD P4P model in Taiwan.

In conclusion, we observed a significantly decreased prevalence of COPD-related ED visits and hospitalizations in patients with COPD in the COPD P4P program at 1 year after enrollment. These findings illustrate that a COPD P4P program can reduce adverse COPD events, including the prevalence of COPD-related ED visits and hospitalizations. However, further assessment of the COPD P4P program's long-term effects on health outcomes by using a wider range of indicators may elucidate the effect of linking health care provider financial incentives with quality improvement in COPD health care management.

## Patient Consent and Ethical Approval

This study was approved by the Institutional Review Board of the Changhua Christian Hospital (approval number 190910). Written informed consent was not required because of the retrospective nature of the investigation.

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## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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## Disclosure

The authors report no conflicts of interest in this work.

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