Online Supplement

Association of Patient and Primary Care Provider Factors with Outpatient COPD Care Quality

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e-METHODS

Chart Abstractions

Four authors (LCF, TLK, NS, and AD) performed chart abstractions for this study. LCF developed a systematic standardized data collection form that was used to abstract patient data. LCF trained TLK, NS, and AD on the use of this form for data abstraction. A data dictionary was created and iteratively revised to ensure data was collected in a standardized fashion. LCF and TLK performed duplicate chart abstractions on ~20% of the cohort to ensure reliability, with discrepancies between reviewers occurring less than 5% of the time.

Outcomes

Our primary outcome was the proportion of guideline-recommended outpatient chronic obstructive pulmonary disease (COPD) care quality measures that patients received through primary or pulmonary specialty care.[1-3] **e-Table 1** outlines patient eligibility and criteria for achievement of each component of the outcome. With the exception of spirometry (within 5 years prior to the index date) and appropriate inhaled therapy (nearest the index date), all measures were assessed within one year prior to the index date.

We considered patients to meet the "respiratory symptom assessment" quality measure if their PCP or pulmonologist documented any of the components of the measure (e.g., documentation of "dyspnea" present or absent, documentation of "cough" present or absent, or documentation of "wheezing" present or absent) in the year prior to enrollment.

Predictors of Outpatient Care Quality

We hypothesized that certain patient and primary care provider (PCP) characteristics would influence the receipt of guideline-recommended outpatient COPD care.

Patient characteristics included:

- Demographics:
  - Age (continuous variable)
  - Sex (categorized as male or female)
  - Insurance status (categorized as Medicaid, Medicare, commercial, or no documented insurance)
  - Marital Status (categorized as Single/Widowed/Divorced vs. Married/Domestic Partner)
  - Race (categorized as white vs. non-white)

- Obesity (defined as a BMI ≥ 30); note that 55 patients did not have BMI recorded, and we thus categorized BMI as < 30, ≥ 30, or missing

- Comorbidities (using ICD-9 codes)
  - Heart Disease (includes a history of congestive heart failure and coronary artery disease)
  - Non-COPD lung disease (includes a history of asthma, prior pneumonia, and pulmonary fibrosis)

- Obstructive sleep apnea
- Depression

- Substance use (including alcohol or intravenous drug use)

- Outpatient healthcare utilization
    - Total number of visits to primary care and pulmonary specialty care in the year prior to index (continuous)
    - Completion of an outpatient pulmonary referral (yes vs. no)

- Continuity of primary care
    - Total number of unique PCPs seen in year prior to index (continuous)
    - Proportion of primary care visits with each patient's most frequent PCP

- Number of hospitalizations for COPD within one year prior to index (continuous)

We specifically excluded smoking status as a patient-level predictor because eligibility for components of the primary outcome depend upon this health-related behavior. We chose to categorize race as a binary variable (white vs. non-white) because of the small number of patients in some racial subgroups, which led to model instability.

We used the characteristics of the PCP each patient saw most frequently in the year prior to index, regardless of that provider's training status (resident, attending, ARNP). We obtained PCP characteristics from data available to University of Washington (UW) faculty within curricula vitae and residency rosters. Characteristics included:

- Gender (categorized as man vs. woman)
- Highest degree attained (categorized as MD vs. ARNP)
- Years since highest degree attained (continuous)
- The proportion of patients in the cohort that the PCP co-managed with a pulmonologist

Statistical Analyses

We used multivariable mixed effects linear and logistic regression models to account for clustering of patients by PCPs. We predicted that each PCP would have a unique practice style and *a priori* chose an independent covariance matrix. As patients were also clustered by primary care clinic site, we had initially intended to include a random intercept by site. However, this led to model overfitting. As patient and PCP characteristics were similar across practice sites (data not shown), we felt that it was reasonable to exclude the random intercept by site from our final models.

As multicollinearity can result in model overfitting, we determined variance inflation factors for each covariate with plan to exclude those with values > 5.[4] We found no evidence of multicollinearity and thus included all covariates in the final analyses.

Sensitivity Analyses

It was possible for patients to meet our study's inclusion criteria and have less than one year of outpatient data within the UW system available for chart abstraction. In addition, although we attempted to ascertain exacerbations within two years prior to the index date, some patients may not have had two full years of data available. Of the 641 patients who met our inclusion criteria, 571 (89.1%) and 534 (83.3%) had one and two full years of data within the UW system, respectively. To partially account for this limitation, we performed a sensitivity analysis in which we restricted the cohort to patients who had one full year of data available prior to the index date.

e-TABLES

e-Table 1. Criteria for achieving components of guideline-recommended care[1-3]

Recommended Care Measure	Criteria for achievement
All Patients	
Spirometry	Completed within 5 years of index date
Respiratory Symptom Assessment	Documented as present or absent any of the following at least once[a,b] - Dyspnea or - Cough/Sputum production or - Wheezing
Oxygen Saturation Assessment[3]	Documented resting or ambulatory oxygen saturation at least once[a,b]
Smoking Status Assessment	Documented at least once[a,b]

Guideline-concordant Inhaled Therapy	Inhaled therapy[c] considered guideline-concordant **except** when:
	
	Undertreatment
	   No LABD prescribed when FEV1/FVC < 0.7 (or unknown) and any of the following were present:
	- mMRC >= 2 or
	- FEV1 < 60% predicted or
	- 1+ COPD exacerbations[d]
	
	Overtreatment
	   LABD prescribed when:
	- FEV1/FVC >= 0.7 & no asthma diagnosis or
	- FEV1/FVC >= 0.7 with asthma but without ICS
	
	   ICS prescribed when:
	- FEV1/FVC >= 0.7 & no asthma diagnosis or
	- No LABD prescribed & no asthma diagnosis or
	- FEV1/FVC < 0.7 & LABD prescribed & FEV1 >= 50% predicted & no history of COPD exacerbations

If Spirometry Performed	
COPD Diagnosis Confirmed	Post-bronchodilator FEV1/FVC < 0.7
If Oxygen Saturation < 88% at Rest or with Ambulation[a,b]	
Prescription for Supplemental Oxygen	Prescribed or recommended but patient declined
If Smoking Tobacco[b]	
Smoking Cessation Intervention	Provider[a] documented the following at least once:[b] - Counseled to quit or - Offered pharmacotherapy (NRT, bupropion or varenicline) or - Prescribed pharmacotherapy
If mMRC >=2 or 1+ COPD Exacerbation[b,d]	
Pulmonary Rehabilitation	Completed or recommended[a, b]

LABD: Long-acting bronchodilator; ICS: Inhaled corticosteroid; mMRC: modified Medical Research Council Score; FEV1: forced expiratory volume in 1 second; FVC: forced vital capacity; NRT: nicotine replacement therapy
a. By primary care physician or pulmonologist
b. Within 1 year of index date
c. Based on therapy prescribed nearest the index date

e-Table 2. Patient- and PCP-level Factors Associated with the Completion of Spirometry[a]

Patient-level Factors	Crude Odds Ratio (95% Confidence Interval)	Adjusted Odds Ratio[b] (95% Confidence Interval)
Age, /10 years	1.02 (0.88 – 1.18)	0.94 (0.76 – 1.14)
Sex		
Male	1.50 (1.08 – 2.07)	1.41 (0.99 – 2.01)
Insurance Status		
Medicare	Referent	Referent
Medicaid	1.04 (0.71 – 1.51)	0.80 (0.51 – 1.25)
Commercial	0.53 (0.27 – 1.05)	0.55 (0.23 – 1.32)
No Documented Insurance	0.94 (0.53 – 1.67)	1.05 (0.58 – 1.92)
Marital Status		
Single/Widowed/Divorced	Referent	Referent
Married/Domestic Part.	1.02 (0.70 – 1.49)	1.02 (0.67 – 1.55)
Race		
White	Referent	Referent
Other	1.13 (0.81 – 1.58)	1.01 (0.69 – 1.47)
Obesity (BMI ≥ 30)	1.12 (0.80 – 1.59)	1.12 (0.77 – 1.61)
Comorbidities		
Heart Disease[c]	1.36 (0.96 – 1.93)	1.04 (0.70 – 1.56)
Obstructive Sleep Apnea	1.60 (1.03 – 2.49)	0.99 (0.60 – 1.65)
Non-COPD Lung Disease[d]	1.45 (1.04 – 2.02)	1.11 (0.73 – 1.70)
Depression	0.95 (0.69 – 1.32)	0.85 (0.59 – 1.20)
Substance Use	1.35 (0.94 – 1.93)	1.38 (0.93 – 2.04)
Outpatient Visits, /visit[e]	1.14 (1.08 – 1.20)	1.15 (1.06 – 1.25)
Completed Pulmonology Referral	13.43 (5.79 – 31.15)	12.48 (4.20 – 37.13)
Number of Different PCPs Seen, /Additional PCP	1.09 (0.97 – 1.24)	0.75 (0.55 – 1.02)
% Clinic Visits with Most Frequent PCP, /10 percentage pts	0.96 (0.90 – 1.03)	0.90 (0.78 – 1.04)
Inpatient Exacerbations, /Exacerbation	1.15 (0.88 – 1.52)	0.89 (0.69 – 1.20)
PCP-level Factors	**Crude Odds Ratio (95% Confidence Interval)**	**Adjusted Odds Ratio[b] (95% Confidence Interval)**
Provider Gender		
Male	0.95 (0.59 – 1.30)	1.00 (0.72 – 1.40)
Time Since Degree Attained, /5yrs	0.90 (0.84 – 0.97)	0.90 (0.83 – 0.98)
Highest Degree Attained		
MD	Referent	Referent
ARNP	0.58 (0.34 – 1.00)	0.59 (0.30 – 1.15)
% Patients PCP Co-manages with Pulmonary, /1 percentage point	3.49 (1.38 – 8.85)	0.42 (0.11 – 1.51)

PCP: primary care provider; BMI: body mass index; MD: allopathic medical doctorate; ARNP: advanced registered nurse practitioner
a. At least once within 5 years of the index date
b. Mixed effects logistic regression adjusted for all patient- and PCP-level factors, with a random intercept for each patient's most frequent PCP
c. Includes coronary artery disease and congestive heart failure
d. Includes asthma, prior pneumonia, and pulmonary fibrosis
e. Includes both PCP and pulmonary visits

e-Table 3. Patient- and PCP-level Factors Associated with the Confirmation of COPD via Spirometry[a]

Patient-level Factors	Crude Odds Ratio (95% Confidence Interval)	Adjusted Odds Ratio[b] (95% Confidence Interval)
Age, /10 years	1.77 (1.37 – 2.28)	1.90 (1.42 – 2.54)
Sex		
Male	1.57 (1.00 – 2.49)	1.83 (1.02 – 3.27)
Insurance Status		
Medicare	Referent	Referent
Medicaid	0.56 (0.34 – 0.92)	0.86 (0.45 – 1.64)
Commercial	0.53 (0.19 – 1.49)	0.35 (0.12 – 1.03)
No Documented Insurance	1.15 (0.48 – 2.79)	1.42 (0.41 – 4.99)
Marital Status		
Single/Widowed/Divorced	Referent	Referent
Married/Domestic Part.	2.87 (1.49 – 5.52)	2.19 (0.95 – 5.03)
Race		
White	Referent	Referent
Other	0.61 (0.39 – 0.96)	0.52 (0.34 – 0.82)
Obesity (BMI ≥ 30)	0.42 (0.26 – 0.67)	0.61 (0.33 – 1.13)
Comorbidities		
Heart Disease[c]	0.62 (0.39 – 0.99)	0.38 (0.20 – 0.72)
Obstructive Sleep Apnea	0.46 (0.27 – 0.78)	0.48 (0.24 – 0.97)
Non-COPD Lung Disease[d]	1.19 (0.75 – 1.88)	1.20 (0.68 – 2.16)
Depression	0.68 (0.43 – 1.07)	0.91 (0.50 – 1.66)
Substance Use	0.66 (0.41 – 1.06)	0.77 (0.43 – 1.37)
Outpatient Visits, /visit[e]	1.00 (0.94 – 1.06)	1.00 (0.91 – 1.11)
Completed Pulmonology Referral	2.66 (1.44 – 4.93)	4.88 (1.92 – 12.41)
Number of Different PCPs Seen, /Additional PCP	0.90 (0.76 – 1.06)	0.75 (0.50 – 1.12)
% Clinic Visits with Most Frequent PCP, /10 percentage pts	1.04 (0.94 – 1.14)	0.89 (0.73 – 1.08)
Inpatient Exacerbations, /Exacerbation	2.41 (1.21 – 4.80)	4.11 (1.70 – 9.95)
PCP-level Factors	Crude Odds Ratio (95% Confidence Interval)	Adjusted Odds Ratio[b] (95% Confidence Interval)
Provider Gender		
Male	1.61 (1.01 – 2.57)	1.71 (0.97 – 3.03)
Time Since Degree Attained, /5yrs	1.00 (0.90 – 1.11)	0.97 (0.83 – 1.13)
Highest Degree Attained		
MD	Referent	Referent
ARNP	0.91 (0.39 – 2.12)	0.82 (0.44 – 1.53)
% Patients PCP Co-manages with Pulmonary, /1 percentage point	1.96 (0.65 – 5.94)	0.39 (0.07 – 2.26)

PCP: primary care provider; BMI: body mass index; MD: allopathic medical doctorate; ARNP: advanced registered nurse practitioner
a. Includes 398 patients who completed spirometry, of whom 295 (74.1%) had fixed airflow obstruction (FEV1/FVC < 0.7)
b. Mixed effects logistic regression adjusted for all patient- and PCP-level factors, with a random intercept for each patient's most frequent PCP
c. Includes coronary artery disease and congestive heart failure
d. Includes asthma, prior pneumonia, and pulmonary fibrosis
e. Includes both PCP and pulmonary visits

e-Table 4. Patient- and PCP-level Factors Associated with the Receipt of Indicated Long-acting Bronchodilators[a]

Patient-level Factors	Crude Odds Ratio (95% Confidence Interval)	Adjusted Odds Ratio[b] (95% Confidence Interval)
Age, /10 years	1.19 (0.98 – 1.45)	1.09 (0.82 – 1.44)
Sex		
Male	0.91 (0.60 – 1.40)	0.89 (0.52 – 1.54)
Insurance Status		
Medicare	Referent	Referent
Medicaid	0.81 (0.50 – 1.32)	0.93 (0.53 – 1.65)
Commercial	0.89 (0.32 – 2.47)	0.96 (0.31 – 2.99)
No Documented Insurance	0.42 (0.20 – 0.86)	0.43 (0.20 – 0.96)
Marital Status		
Single/Widowed/Divorced	Referent	Referent
Married/Domestic Part.	1.12 (0.70 – 1.81)	1.10 (0.64 – 1.90)
Race		
White	Referent	Referent
Other	0.79 (0.51 – 1.21)	0.60 (0.35 – 1.04)
Obesity (BMI ≥ 30)	1.14 (0.72 – 1.80)	1.06 (0.60 – 1.85)
Comorbidities		
Heart Disease[c]	1.06 (0.68 – 1.65)	0.73 (0.46 – 1.16)
Obstructive Sleep Apnea	1.43 (0.80 – 2.53)	1.05 (0.50 – 2.19)
Non-COPD Lung Disease[c]	1.24 (0.82 – 1.87)	1.06 (0.64 – 1.76)
Depression	0.84 (0.55 – 1.29)	0.76 (0.47 – 1.23)
Substance Use	0.82 (0.52 – 1.30)	0.83 (0.47 – 1.48)
Outpatient Visits, /visit[e]	1.05 (1.00 – 1.11)	1.08 (0.98 – 1.20)
Completed Pulmonology Referral	2.43 (1.45 – 4.05)	1.59 (0.69 – 3.64)
Number of Different PCPs Seen, /Additional PCP	0.98 (0.84 – 1.13)	0.71 (0.49 – 1.02)
% Clinic Visits with Most Frequent PCP, /10 percentage pts	1.00 (0.92 – 1.10)	0.88 (0.74 – 1.05)
Inpatient Exacerbations, /Exacerbation	1.75 (1.23 – 2.50)	1.90 (1.32 – 2.72)
PCP-level Factors	**Crude Odds Ratio (95% Confidence Interval)**	**Adjusted Odds Ratio[b] (95% Confidence Interval)**
Provider Gender		
Male	0.73 (0.48 – 1.11)	0.72 (0.46 – 1.16)
Time Since Degree Attained, /5yrs	0.95 (0.87 – 1.05)	0.91 (0.82 – 1.01)
Highest Degree Attained		
MD	Referent	Referent
ARNP	0.84 (0.41 – 1.72)	0.85 (0.32 – 2.29)
% Patients PCP Co-manages with Pulmonary, /1 percentage point	3.53 (1.21 – 10.32)	1.51 (0.40 – 5.74)

PCP: primary care provider; BMI: body mass index; MD: allopathic medical doctorate; ARNP: advanced registered nurse practitioner
a. Includes 364 patients with an indication for a long-acting bronchodilator, of whom 202 (55.5%) received appropriate treatment
b. Mixed effects logistic regression adjusted for all patient- and PCP-level factors, with a random intercept for each patient's most frequent PCP
c. Includes coronary artery disease and congestive heart failure
d. Includes asthma, prior pneumonia, and pulmonary fibrosis
e. Includes both PCP and pulmonary visits

e-Table 5. Patient- and PCP-level Factors Associated with the Proportion of COPD Care Quality Measures Achieved (1 Year of Data Available)[a]

Patient-level Factors	Univariate β_1 coefficient (95% Confidence Interval)	Multivariate β_1 coefficient[b] (95% Confidence Interval)
Age, /10 years	1.0% (-0.4%, 2.4%)	0.9% (-0.8%, 2.7%)
Sex		
Male	4.0% (0.9%, 7.0%)	4.2% (1.3%, 7.2%)
Insurance Status		
Medicare	Referent	Referent
Medicaid	1.5% (-2.0%, 5.1%)	1.2% (-2.4%, 4.8%)
Commercial	-2.7% (-9.6%, 4.2%)	-0.6% (-7.0%, 5.7%)
No Documented Insurance	-0.2% (-6.1%, 5.8%)	1.4% (-4.1%, 6.9%)
Marital Status		
Single/Widowed/Divorced	Referent	Referent
Married/Domestic Part.	1.1% (-2.5%, 4.7%)	-0.5% (-4.4%, 3.4%)
Race		
White	Referent	Referent
Other	-0.2% (-3.3%, 2.9%)	-1.5% (-3.9%, 0.9%)
Obesity (BMI ≥ 30)	0.0% (-3.3%, 3.2%)	0.7% (-1.8%, 3.2%)
Comorbidities		
Heart Disease[c]	1.2% (-2.1%, 4.4%)	-1.6% (-4.6%, 1.5%)
Obstructive Sleep Apnea	1.2% (-2.6%, 5.1%)	-3.3% (-6.6%, 0.0%)
Non-COPD Lung Disease[d]	2.3% (-0.8%, 5.4%)	-0.2% (-3.2%, 2.8%)
Depression	0.5% (-2.6%, 3.6%)	1.3% (-1.4%, 4.0%)
Substance Use	-0.1% (-3.2%, 3.1%)	-0.2% (-3.4%, 3.1%)
Outpatient Visits, /visit[e]	1.2% (0.8%, 1.6%)	0.8% (0.2%, 1.4%)
Completed Pulmonology Referral	18.8% (15.1%, 22.5%)	17.9% (13.0%, 22.8%)
Number of Different PCPs Seen, /Additional PCP	1.2% (0.0%, 2.3%)	-1.2% (-3.2%, 0.7%)
% Clinic Visits with Most Frequent PCP, /10 percentage pts	-0.5% (-1.2%, 0.2%)	-0.5% (-1.4%, 0.4%)
Inpatient Exacerbations, /Exacerbation	2.1% (-0.4%, 4.5%)	0.3% (-2.2%, 2.7%)
PCP-level Factors	Univariate β_1 coefficient (95% Confidence Interval)	Multivariate β_1 coefficient[b] (95% Confidence Interval)
Provider Gender		
Male	-4.1% (-7.1%, -1.0%)	-3.4% (-6.1%, -0.8%)
Time Since Degree Attained, /5yrs	-1.0% (-1.7%, -0.3%)	-0.7% (-1.4%, -0.1%)
Highest Degree Attained		
MD	Referent	Referent
ARNP	-1.9% (-7.2%, 3.4%)	-0.5% (-4.8%, 3.7%)
% Patients PCP Co-manages with Pulmonary, /1 percentage point	14.8% (6.8%, 22.7%)	-5.0% (-12.7%, 2.6%)

PCP: primary care provider; BMI: body mass index; MD: allopathic medical doctorate; ARNP: advanced registered nurse practitioner

a. N=571

b. Mixed effects linear model adjusted for all patient factor and PCP-level factors, with a random intercept for each patient's most frequent PCP

c. Includes coronary artery disease and congestive heart failure

d. Includes asthma, prior pneumonia, and pulmonary fibrosis

e. Includes both PCP and pulmonary visits

e-Table 6. Mean Difference in Proportion of COPD Care Quality Measures Achieved Associated with Patient- and PCP-level Factors (PCP Visits Only)

Patient-level Factors	Univariate β_1 coefficient (95% Confidence Interval)	Multivariate β_1 coefficient[a] (95% Confidence Interval)
Age, /10 years	0.8% (-0.5%, 2.0%)	0.6% (-1.0%, 2.3%)
Sex		
Male	3.7% (0.9%, 6.4%)	3.8% (0.9%, 6.7%)
Insurance Status		
Medicare	Referent	Referent
Medicaid	1.4% (-1.8%, 4.6%)	0.7% (-2.7%, 4.0%)
Commercial	-1.9% (-7.9%, 4.1%)	-0.3% (-6.3%, 5.7%)
No Documented Insurance	1.7% (-3.2%, 6.6%)	3.3% (-1.3%, 7.9%)
Marital Status		
Single/Widowed/Divorced	Referent	Referent
Married/Domestic Part.	1.5% (-1.7%, 4.7%)	0.2% (-3.2%, 3.6%)
Race		
White	Referent	Referent
Other	-0.7% (-3.6%, 2.1%)	-1.5% (-4.0%, 1.0%)
Obesity (BMI ≥ 30)	-0.3% (-3.2%, 2.7%)	0.2% (-2.4, 2.8%)
Comorbidities		
Heart Disease[b]	2.0% (-1.0%, 4.9%)	-0.3% (-3.2%, 2.6%)
Obstructive Sleep Apnea	0.7% (-2.9%, 4.3%)	-2.4% (-5.7%, 0.9%)
Non-COPD Lung Disease[c]	1.9% (-0.9%, 4.6%)	-0.0% (-3.0%, 2.9%)
Depression	0.6% (-2.2%, 3.4%)	0.5% (-2.2%, 3.2%)
Substance Use	0.9% (-2.1%, 4.0%)	0.3% (-2.8%, 3.3%)
Outpatient Visits with PCPs, /visit	1.0% (0.5%, 1.4%)	1.2% (0.7%, 1.7%)
Completed Pulmonology Referral	11.6% (8.0%, 15.2%)	11.3% (6.9%, 15.7%)
Number of Different PCPs Seen, /Additional PCP	1.3% (0.3%, 2.4%)	-1.5% (-3.3%, 0.3%)
% Clinic Visits with Most Frequent PCP, /10 percentage pts	-0.4% (-1.0%, 0.1%)	-0.6% (-1.5%, 0.3%)
Inpatient Exacerbations, /Exacerbation	2.0% (-0.2%, 4.2%)	0.8% (-1.4%, 3.1%)
PCP-level Factors	**Univariate β_1 coefficient (95% Confidence Interval)**	**Multivariate β_1 coefficient[a] (95% Confidence Interval)**
Provider Gender		
Male	-3.4% (-6.2%, -0.7%)	-2.7% (-5.2%, -0.2%)
Time Since Degree Attained, /5yrs	-1.2% (-1.8%, -0.6%)	-1.1% (-1.7%, -0.5%)
Highest Degree Attained		
MD	Referent	Referent
ARNP	-3.4% (-8.1%, 1.4%)	-2.0% (-6.4%, 2.4%)
% Patients PCP Co-manages with Pulmonary, /1 percentage point	9.3% (2.3%, 16.4%)	-1.8% (-9.2%, 5.6%)

PCP: primary care provider; BMI: body mass index; MD: allopathic medical doctorate; ARNP: advanced registered nurse practitioner
a. Mixed effects linear model adjusted for all patient- and PCP-level factors, with a random intercept for each patient's most frequent PCP.
b. Includes coronary artery disease and congestive heart failure
c. Includes asthma, prior pneumonia, and pulmonary fibrosis

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