Time and Economic Burden of Comorbidities Among COPD Inpatients

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Abstract. Chronic obstructive pulmonary disease (COPD) is a major public health problem and usually associated with various comorbidities. Base on electronic health records of inpatients, aged 40 to 80 years old, from 169 hospitals located across China between 2013 and 2014, this paper summarized 27 comorbidities of COPD and compared the time and economic burdens of COPD patients to non-COPD patients. The 17 comorbidities included in Charlson Comorbidity Index (CCI) and 10 additional comorbidities were employed while odds ratios were considered to compare differences. The results disclosed that COPD patients had higher comorbidity burdens than non-COPD patients did. Moreover, COPD patients had 6.40 % more hospital stay and 12.96 % lower medical cost. Seven morbidities had positive correlations with hospital stay and medical cost, which indicated that COPD patients should be paid more attention to those comprehensive comorbidities when making therapeutic plans.

Keywords: COPD · Comorbidity · Time burden · Economic burden · Inpatient · CCI · Population study

1 Introduction

Chronic obstructive pulmonary disease (COPD) is a preventable and treatable disease state characterized by airflow limitation that is not fully reversible [1]. Depending on World Health Organization (WHO), COPD is the third major killers during the past decade, which resulted in 3.1 million deaths in 2012 [2]. Furthermore, COPD places heavy economic burdens on patients. In 2010, the cost of COPD in the USA was projected to be approximately US $50 billion, which includes $20 billion in indirect costs and $30 billion in direct health care expenditures [3].

A variety of comorbidities are associated with COPD, which markedly affect health outcomes in COPD [4]. COPD can no longer be considered a disease only of the lungs, as it is often associated with a wide variety of systemic consequences [5]. For example, researchers found that patients with COPD are in an increased risk of developing type 2

diabetes, because some aspects of inflammation can predict the development of diabetes and glucose disorders [6]. Charlson Comorbidity Index (CCI) and its modified comorbidity index were used widely to measure patients' comorbidity conditions [11]. In addition, researchers disclosed that Medicaid COPD patients had higher comorbidity burdens, more medical claims, and more medical cost than did patients without COPD [8]. However, existing research works related to this issue were based on small data sets, normally thousands of patients. Health big data analysis may find more interesting results.

In this paper, we evaluated the comorbidity burdens of COPD patients through mining a large Electronic Health Records data set. The time and economic burdens of inpatients with COPD were analyzed and compared with non-COPD inpatients. The object of this study is to analyze the degrees of time and economic impact among COPD inpatients with different comorbidities.

The rest of this paper is organized as follows. Section 2 provided a description to our data set and methods utilized in this study. We reported our statistical results in Sect. 3. In Sect. 4, we discussed and concluded the paper.

2   Data and Methods

2.1   Data Set

The Electronic Health Records (EHRs) being analyzed in this study were provided by the Chinese National Surveillance System. This surveillance system had been adopted by 192 hospitals located across China. In order to maintain a high data quality, EHRs from 169 hospitals for 2013 to 2014 were used in this research. The patient's personal and medical information was collected by clinical doctors while the patient was hospitalized. The data was then summarized by trained staff and checked by certified agencies before the data was submitted to the surveillance system. Thus the information included in the EHRs should be highly reliable and objective.

The study population was limited to inpatients aged 40 to 80 years old. Patients younger than 40 years were excluded because they usually have a low risk for COPD. Patients older than 80 years were also excluded due to the limited number of data records.

Only patient's sex, age, time, cost, and clinical diagnostic information were utilized to perform our analysis. Patient's identity-related information was masked automatically by the system before we started our study.

2.2   Measures of Comorbidity Burden

Comorbidity burden of inpatients with COPD was mainly evaluated by the CCI with the Sundararajan modification [9, 10]. The CCI was a useful tool for health researchers to measure comorbid disease status in health databases. It defined 17 comorbidities through reviewing hospital charts and assessed their relevancies in the prediction of 1-year mortality. A weighted score was assigned to each comorbidities, and the sum of the score (defined as CCI score) is identified as an indicator of disease burden, and a

robust estimator of mortality [9]. Because COPD is a kind of chronic pulmonary disease (CPD), we excluded COPD patients from CPD and considered CPD without COPD as a unique class of diseases. Moreover, 10 additional conditions, including 6 conditions according to Lin [11] and 4 commonly observed comorbidities among patients with COPD in our data set, were also taken into account in our study.

All 27 comorbidities were identified through International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM), which is the statistical classification of disease published by the WHO.

Four measures were employed to evaluate the comorbidity burden: (1) mean CCI score; (2) prevalence of each morbidity and odds ratio (OR), which described the ratio of the odds for a patient with COPD and a specific comorbidity to the odds for a patient without COPD and with that same comorbidity; (3) mean number of comorbidities; and (4) total number of comorbidities (categorized as 0, 1, 2, 3, and ≥4).

2.3 Measures of Time and Economic Burdens

In evaluating the time burden of inpatients with COPD, we use the duration of hospital stays, which defined as the total number of nights staying in a hospital. In our research design, if the admission date is the same as the discharge date in one EHR, we defined the hospital stay of this patient as 0.

In order to assess the economic burden, total medical cost, which obtained directly from EHRs, was used. Total medical cost contained the out-of-pocket expenses that an inpatient was required to pay in hospital.

2.4 Analysis

Independent-samples t-test was used to compare mean CCI score, mean number of comorbidities, mean hospital stay, and mean medical cost for patients with COPD and patients without COPD. Odds ratio (OR) of each comorbidity was predicted by binary logistic regression while Wald chi-square statistic tested the unique contribution of each comorbidity. Incremental hospital stay of each comorbidity was calculated by taking the difference of mean hospital stay between COPD and non-COPD patients; the same process was repeated for obtaining the incremental medical cost.

3 Results

3.1 Characteristics of the Study Population

EMRs from 196,388 COPD and 4,332,068 non-COPD patients were employed in our study. The demographic characteristics of the study population are summarized in Table 1. Compared with non-COPD patients, COPD patients have a significantly higher mean age (66.76 vs. 57.29), higher male hospitalization rate (68.92 % vs. 54.44 %), and prefer medical insurance to cover their hospitalization cost (68.40 % vs.

Table 1. Characteristics of the study population

	Original sample (n = 4,528,456)	
	COPD (n = 196,388)	N-COPD (n = 4,332,068)
Mean age, years (s.d.)	66.76 (8.923)	57.29 (10.474)
Male, %	68.92	54.44
Level of hospital, %		
Grade 3-A	70.48	76.79
Grade 3-B	12.48	10.78
Grade 3-C	0.97	1.11
Grade 2	16.07	11.33
Payment method, %		
Medical insurance	68.40	56.52
Out-of-pocket expenses	24.91	34.89
Other	6.69	8.58

COPD: chronic obstructive pulmonary disease; s.d.: standard deviation.

56.52 %). Moreover, different level of the hospital was of comparable admission rate between COPD patients and non-COPD patients.

3.2   Comorbidity Burden

The comorbidity prevalence for COPD and non-COPD patients was summarized in Table 2. In overall, the comorbidity burden is significantly higher in COPD patients than non-COPD patients (mean CCI score: 1.35 vs. 1.13; mean number of comorbidities: 1.73 vs. 1.11).

For comorbidities included in the CCI, the prevalence rates of congestive heart failure (19.23 %), cerebrovascular disease (16.11 %), any malignancy (13.41 %), diabetes (12.61 %), and chronic pulmonary disease (12.15 %) were high in patients with COPD. Although some of them were also prevalent in patients without COPD, patients with COPD were significantly more likely to have chronic pulmonary disease (OR: 12.095), congestive heart failure (OR: 5.468), myocardial infarction (OR: 1.521), and cerebrovascular disease (OR: 1.391). The prevalence rates of other comorbidities included in CCI were either too low to report or almost similar for patients with and without COPD.

Among the 10 additional comorbidities, 6 comorbidities had high prevalence rates. Patients with COPD were more likely to have pulmonary heart disease (18.51 %, OR: 54.464), atherosclerosis (5.44 %, OR: 2.000), hypertension (34.66 %, OR: 1.569), and gastritis and duodenitis (18.51 %, OR: 1.468). Cholelithiasis (5.29 %, OR: 1.258) and disorders of lipoprotein metabolism (7.14, OR: 1.116) did not have a big difference between COPD patients and non-COPD patients. Because of different data acquisition methods, prevalence rates of 4 comorbidities proposed by Lin [11] were very low. Therefore, we removed those 4 comorbidities and comorbidities with low prevalence rates in CCI from our study.

Table 2. Comorbidity prevalence for COPD and non-COPD patients

Comorbidity	COPD (n = 196388)	N-COPD (n = 4332068)	Odds ratio (95 % CI)	p-value
Mean CCI score (s.d.)	1.35(1.788)	1.13(1.839)	-	<0.001
Comorbidities included in the CCI				
Myocardial infarction	2.17 %	1.43 %	1.521 (1.474, 1.570)	<0.001
Congestive heart failure	19.23 %	4.17 %	5.468 (5.402, 5.535)	<0.001
Peripheral vascular disease	0.28 %	0.20 %	-[a]	-
Cerebrovascular disease	16.11 %	12.13 %	1.391 (1.374, 1.409)	<0.001
Dementia	0.35 %	0.16 %	-[a]	-
Chronic pulmonary disease[b]	12.15 %	1.13 %	12.095 (11.900, 12.292)	<0.001
Rheumatologic disease	1.15 %	0.98 %	1.169 (1.120, 1.220)	<0.001
Peptic ulcer disease	2.03 %	1.62 %	1.254 (1.214, 1.295)	<0.001
Mild liver disease	1.97 %	4.08 %	0.472 (0.457, 0.487)	<0.001
Diabetes	12.61 %	12.66 %	0.995 (0.982, 1.009)	0.4681
Diabetes with chronic complications	1.79 %	2.62 %	0.676 (0.654, 0.699)	<0.001
Hemiplegia or paraplegia	0.12 %	0.18 %	-[a]	-
Renal disease	3.98 %	3.61 %	1.109 (1.084, 1.135)	<0.001
Any malignancy, including leukemia and lymphoma	13.41 %	15.08 %	0.872 (0.860, 0.883)	<0.001
Moderate or severe liver disease	0.89 %	0.86 %	-[a]	-
Metastatic solid tumor	4.26 %	4.81 %	0.881 (0.862, 0.901)	<0.001
AIDS	0.04 %	0.03 %	-[a]	-
Comorbidities not included in the CCI				
Hypertension	34.66 %	25.26 %	1.569 (1.554, 1.584)	<0.001
Depression	0.25 %	0.28 %	-[a]	-
Sleep apnea	0.54 %	0.21 %	-[a]	-
Tobacco use	0.00 %	0.00 %	-[a]	-
Edema	0.24 %	0.11 %	-[a]	-
Pulmonary heart disease	18.51 %	0.42 %	54.464 (53.463, 55.484)	<0.001
Gastritis and duodenitis	8.27 %	5.79 %	1.468 (1.444, 1.492)	<0.001
Disorders of lipoprotein metabolism	7.14 %	6.44 %	1.116 (1.097, 1.136)	<0.001
Atherosclerosis	5.44 %	2.80 %	2.000 (1.960, 2.041)	<0.001

(*Continued*)

Table 2. (*Continued*)

Comorbidity	COPD (n = 196388)	N-COPD (n = 4332068)	Odds ratio (95 % CI)	p-value
Cholelithiasis	5.29 %	4.25 %	1.258 (1.232, 1.283)	<0.001
Mean number of comorbidities (s.d.)				
	1.73(1.306)	1.11(1.209)	-	<0.001
Total number of comorbidities				
0	18.05 %	40.12 %	0.329 (0.325, 0.333)	<0.001
1	29.64 %	27.94 %	1.087 (1.076, 1.097)	<0.001
2	27.22 %	18.74 %	1.622 (1.605, 1.638)	<0.001
3	15.56 %	8.56 %	1.968 (1.943, 1.993)	<0.001
≥4	9.53 %	4.64 %	2.166 (2.132, 2.200)	<0.001

AIDS: acquired immune deficiency syndrome; CCI: Charlson Comorbidity Index; CI: confidence interval; COPD: chronic obstructive pulmonary disease.
[a]Odds ratio was not reported because too few patients had this comorbidity. [b]Excluding COPD.

Table 3. Incremental stay and cost for COPD and non-COPD cohorts by comorbidity

Comorbidity[a]	Mean stay		Δ day	p-value	Mean Cost, $		Δ cost	p-value
	COPD	N-COPD			COPD	N-COPD		
Overall	11.97	11.25	0.72	<0.001	2610.97	2999.84	−388.87	<0.001
Comorbidities included in the CCI								
Myocardial infarction	11.34	10.35	0.99	<0.001	3638.20	5378.96	−1740.77	<0.001
Congestive heart failure	11.79	11.52	0.27	<0.001	2511.15	3991.01	−1479.87	<0.001
Cerebrovascular disease	13.35	12.98	0.37	<0.001	2808.08	3200.67	−392.59	<0.001
Chronic pulmonary disease[b]	11.78	11.52	0.26	0.001	2250.20	2318.70	−68.50	0.008
Rheumatologic disease	12.70	11.79	0.91	<0.001	2523.94	2274.80	249.14	0.001
Peptic ulcer disease	12.45	11.47	0.98	<0.001	2967.86	2901.89	65.97	0.316
Mild liver disease	13.08	12.00	1.08	<0.001	4112.35	3921.73	190.62	0.042
Diabetes	12.78	12.37	0.41	<0.001	2869.38	2997.34	−127.96	<0.001
Diabetes with chronic complications	13.19	12.80	0.39	0.023	2569.23	2172.60	396.63	<0.001
Renal disease	13.88	14.72	-0.84	<0.001	3394.73	3167.55	227.18	<0.001
Any malignancy, including leukemia and lymphoma	14.08	13.16	0.92	<0.001	4182.19	4374.48	−192.28	<0.001
Metastatic solid tumor	13.07	12.03	1.04	<0.001	3939.17	3814.40	124.76	0.010
Comorbidities not included in the CCI								
Hypertension	12.38	11.83	0.55	<0.001	2642.71	3016.78	−374.06	<0.001
Pulmonary heart disease	11.86	13.69	-1.83	<0.001	2290.90	4821.00	−2530.10	<0.001
Gastritis and duodenitis	11.62	10.32	1.30	<0.001	2296.59	2156.12	140.47	<0.001
Disorders of lipoprotein metabolism	11.50	10.87	0.63	<0.001	2257.23	2296.38	−39.15	0.106

(*Continued*)

Table 3. (*Continued*)

Comorbidity[a]	Mean stay		Δ day	p-value	Mean Cost, $		Δ cost	p-value
	COPD	N-COPD			COPD	N-COPD		
Atherosclerosis	12.07	11.45	0.62	<0.001	2566.75	2469.75	97.00	0.001
Cholelithiasis	12.14	11.11	1.03	<0.001	2805.84	3100.36	−294.53	<0.001

AIDS: Acquired Immune Deficiency Syndrome; CCI: Charlson Comorbidity Index; COPD: Chronic Obstructive Pulmonary Disease;

[a]8 comorbidities with <1 % of prevalence were excluded. These comorbidities were peripheral vascular disease, dementia, hemiplegia or paraplegia, moderate or severe liver disease, AIDS, depression, sleep apnea, edema.

[b]Excluding COPD.

As for the total number of comorbidities, the rates of patients with and without COPD had 1 comorbidity were comparable (29.64 % vs. 27.94 %). However, 27.22 %, 15.56 %, and 9.53 % of COPD patients had 2, 3 and ≥4 comorbidities, respectively, compared to 18.74 %, 8.56 %, and 4.64 % in patients without COPD. In terms of 27 comorbidities proposed, only 18.05 % COPD patients had none comorbidity compared to 40.12 % in non-COPD patients.

3.3   Incremental Hospital Stay and Medical Cost by Comorbidity

Incremental hospital stay and medical cost were calculated for 18 remaining comorbidities and summarized in Table 3. In general, patients with COPD had 6.40 % higher hospital stay than non-COPD patients (11.97 vs. 11.25, p < 0.001). Gastritis and duodenitis (11.62 vs. 10.32), mild liver disease (13.08 vs. 12.00), metastatic solid tumor (13.07 vs. 12.03), and cholelithiasis (12.14 vs. 11.11) had the biggest incremental hospital stay. An overwhelming majority of comorbidities, except renal disease and pulmonary heart disease, had positive incremental hospital stay.

However, the medical cost of COPD patients was 12.96 % lower than non-COPD patients ($2610.97 vs. $2999.84, p < 0.001). Compared with non-COPD patients, COPD patients who had pulmonary heart disease ($2290.90 vs. $4821.00), myocardial infarction ($3638.20 vs. $5378.96), and congestive heart failure ($2511.15 vs. $3991.01) had the biggest decline in medical cost. Among comorbidities with significantly difference (p < 0.05), only 7 of 16 comorbidities had positive medical cost. COPD patients who had diabetes with chronic complications ($2569.23 vs. $2172.60), rheumatologic disease ($2523.94 vs. $2274.80), and renal disease ($3394.73 vs. $3167.55) had higher medical cost than non-COPD patients. In addition, the medical cost of patients with peptic ulcer disease and disorders of lipoprotein metabolism did not show significant differences.

4   Discussion and Conclusion

In our research, prevalence rates of 27 comorbidities as well as their time and economic implications had been investigated among inpatients with and without COPD. With higher mean CCI score, higher ORs for 13 out of the 18 comorbidities examined,

higher mean number of comorbidities, and higher total number of comorbidities, we found that COPD patients had bigger comorbidity burden. We also found that COPD patients with most of the proposed comorbidities had incremental medical time, measured by hospital stay, compared with non-COPD patients, which indicated the patients with COPD should be paid more attention to comprehensive comorbidity risk when making therapeutic plans. In addition, although our study disclosed the reduced medical cost among COPD patients with 18 comorbidities, there were still 7 comorbidities with considerably incremental medical cost which should be focused on.

The results of this study showed that CCI was an effective way to measure comorbidity burden. Even though it was initially put forward for mortality analysis, CCI gave a clear and concise list of the most important comorbidities. The weight score of comorbidities in CCI and the simple calculation method were useful in measuring comorbidities burden in our case study as well. Besides, prevalent comorbidities for the specific disease were as important as comorbidities in CCI. In our study, gastritis and duodenitis together with atherosclerosis was two important comorbidities which prevalent in COPD patients.

There were a few limitations in this study. First, although our inpatients data had been examined by professional inspectors before being submitted to the surveillance system, some comorbidities (e.g. depression) or conditions (e.g. tobacco use), which were easy to be neglected, may escape medical staffs notice. Second, CCI is a common approach to evaluate patient's mortality. However, it may not be the best index in evaluating patient's comorbidity burden. The Comorbidity-Poly pharmacy Score [12] and the Elixhauser Comorbidity Measure [13] are both potentially useful measures. Third, the measures, which proposed evaluating time and economic implications, were somewhat simple and preliminary. More systematic and comprehensive evaluation system would give a more accurate description of the time and economic burdens among patients.

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