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# Identifying Distinct Healthcare Pathways During Episodes of Chronic Obstructive Pulmonary Disease Exacerbations

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**Abstract:** Healthcare pathways are important to measure because they are expected to affect outcomes. However, they are challenging to define because patients exhibit heterogeneity in their use of healthcare services. The objective of this study was to identify and describe healthcare pathways during episodes of chronic obstructive pulmonary disease (COPD) exacerbations.

Linked administrative databases from Saskatchewan, Canada were used to identify a cohort of newly diagnosed COPD patients and their episodes of healthcare use for disease exacerbations. Latent class analysis (LCA) was used to classify the cohort into homogeneous pathways using indicators of respiratory-related hospitalizations, emergency department (ED) visits, general and specialist physician visits, and outpatient prescription drug dispensations. Multinomial logistic regression models tested patients' demographic and disease characteristics associated with pathway group membership. The most frequent healthcare contact sequences in each pathway were described. Tests of mean costs across groups were conducted using a model-based approach with $\chi^2$ statistics.

LCA identified 3 distinct pathways for patients with hospital- (n = 963) and ED-initiated (n = 364) episodes. For the former, pathway group 1 members followed complex pathways in which multiple healthcare services were repeatedly used and incurred substantially higher costs than patients in the other pathway groups. For patients with an ED-initiated episode, pathway group 1 members also had higher costs than other groups. Pathway groups differed with respect to patient demographic and disease characteristics. A minority of patients were discharged from ED or hospital, but did not have any follow-up care during the remainder of their episode.

Patients who followed complex pathways could benefit from case management interventions to streamline their journeys through the healthcare system. The minority of patients whose pathways were not consistent with recommended follow-up care should be further investigated to fully align COPD treatment in the province with recommended care practices.

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**Abbreviations**: BIC = Bayesian-Schwarz Information Criterion, CIHI = Canadian Institute for Health Information, COPD = chronic obstructive pulmonary disease, ED = emergency department, GP = general practitioner, LCA = Latent class analysis, SABAs = short-acting beta agonists.

## INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a leading cause of morbidity and is annually responsible for up to 3 million deaths worldwide.[1] COPD patients are heavy users of healthcare services and are responsible for up to one-quarter of all hospitalizations and emergency department (ED) visits, and more than one-fifth of ambulatory visits.[2] COPD patients may experience multiple acute exacerbations of symptoms annually; treatment often requires an ED visit or hospitalization.[3,4] Patients may also receive follow-up care from their primary care provider or a specialist physician, and might require additional medications.[5] Accordingly, an exacerbation episode may require contact with a number of different healthcare providers and services and the healthcare pathway, the patient's journey through the healthcare system during COPD exacerbations, will not be the same for every patient.[6]

Studies have investigated the economic burden of COPD exacerbations,[2,4] and the risk factors associated with them,[7,8] but little is known about the healthcare pathways that patients follow during episodes of exacerbation, and how these influence outcomes such as cost. Understanding pathways during exacerbations could help care providers anticipate the needs of patients.[2] Also, pathway analysis can guide quality of care initiatives by identifying patients who may benefit the most from case management interventions.[9]

Healthcare pathways can be investigated using an episode-of-care data system, which collects all services related to the treatment of a specific health condition.[10] Health services utilization within a care pathway can be characterized by duration,[11] intensity (ie, frequency of contacts),[12] and sequence of contacts (ie, trajectories).[6] Latent class analysis (LCA) has previously been used to characterize healthcare utilization

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profiles based on intensity of use.[13,14] However, the method could also be used to identify pathways during episodes of care for patients with complex health conditions.

The objective of this study was to identify and describe healthcare pathways during episodes of COPD exacerbations, focusing on hospital- and ED-initiated episodes. These exacerbations are moderate to severe in nature,[15] and routinely incur the highest healthcare costs.[16]

## METHODS

### Data Sources

We used population-based administrative health data from the province of Saskatchewan, Canada, which has a population of approximately 1.1 million according to the 2011 Statistics Canada Census. Like all Canadian provinces, Saskatchewan has a universal healthcare program, which means that virtually all residents are eligible for health insurance coverage. The province maintains multiple administrative health databases in electronic format, which can be anonymously linked via a unique personal health number.[17]

Episodes of care for COPD exacerbations were constructed using databases that capture primary, emergency, and acute care services for provincial health insurance beneficiaries; these include physician billing claims, ED visit records, hospital discharge abstracts, and prescription drug dispensation records. A hospital discharge abstract is completed when a patient is discharged from an acute care facility. Up to 25 diagnoses are recorded using the International Classification of Diseases, 10th Revision, Canada (*ICD-10-CA*) codes on each record. Information on emergency care is collected in the ED database; which captures up to 16 diagnoses on each record using *ICD-10-CA*. Physician billing claims contain information submitted by physicians, with a single diagnosis recorded on each claim using 3-digit *ICD-9* codes. Prescription drug dispensation records contain information on drugs dispensed in outpatient settings, including the date of dispensation, costs, and national drug identification numbers. The population registry and vital statistics registry were also used in the study. They contain demographic information, as well as dates of health insurance coverage and death.

Data were accessed and analyzed at the provincial Health Quality Council in accordance with a standing data sharing agreement between the organization and the provincial Ministry of Health. Ethics approval for the research was received from the University of Saskatchewan Biomedical Research Ethics Board.

### Study Design and Cohort Selection

The study adopted a retrospective cohort design. The cohort was composed of adults (older than 35 years) who were newly diagnosed with COPD between April 1, 2007 and March 31, 2011, and were residents of Saskatoon and Regina Qu'Appelle health regions, 2 of 12 health regions in Saskatchewan and the only ones that contain major urban centers (population >200,000 in each center) and together account for just over half of the provincial population.

We used the following validated case definitions to identify individuals with COPD: ≥1 hospitalizations with a diagnosis of COPD in any diagnosis field, ≥1 physician visits with a diagnosis of COPD.[18] This case definition has a sensitivity of 85.0% and a specificity of 78.4% when compared with clinical evaluation by a physician.[2] The index date of COPD diagnosis was the earliest hospitalization or physician visit date for COPD. Cases were identified from hospital discharge abstracts using the following *ICD-10-CA* codes: J41, J42, J43 or J44, whereas cases in the physician billing claims were identified with *ICD-9* codes 491, 492, or 496.

We used a look-back period of 5 years from the index date to determine whether or not a patient had a previous COPD diagnosis. We selected this duration of time based on previous research,[19] which showed that most adults with clinically significant COPD will contact the healthcare system at least once in this period. The cohort was limited to individuals who had continuous provincial health insurance coverage from 5 years before their index date until death or March 31, 2012, whichever came first. This restriction allowed us to identify incidence COPD cases and also capture all insured healthcare contacts during the episode.

### Defining Episodes of Care for COPD Exacerbations

All episodes of COPD exacerbations following the index diagnosis were defined using the healthcare services, which initiated, continued, and ended them. We identified episodes of care based on a method developed by the Canadian Institute for Health Information (CIHI), a national non-profit organization that provides standardized methods and data sources for health services research, for ascertaining COPD exacerbations.[20] Hospital- or ED-initiated episodes had a COPD diagnosis in the most responsible diagnosis field, or a diagnosis of an acute lower respiratory tract infection in the most responsible diagnosis field and a diagnosis of other COPD (*ICD-10-CA* code J44) in the second diagnosis field. Physician visit-initiated episodes were defined by an *ICD-9* code for COPD or respiratory infection and had to be accompanied by outpatient dispensation of a drug used to treat acute exacerbations of COPD, including antibiotics, systemic corticosteroids, short-acting beta agonists (SABAs), and SABAs combined with anticholinergics within 2 days of a physician visit. An algorithm was used to define the episode-initiating service in cases in which multiple services were used on the date the episode started. When physician services and hospital (or ED) services were received on the same date, and the billing claims indicated that the physician provided the service in a hospital (or ED), the episode-initiating service was taken as hospitalization (or ED visit). Otherwise, the episode-initiating service was taken as physician visit. When ED visit and hospitalization occurred on the same date, the ED visit was the initiating service. Since the study focused on moderate-to-severe exacerbations,[15] only the hospital- and ED-initiated episodes were included.

An episode continued if there were respiratory-related hospitalizations, ED, GP, or specialist visits that followed the initiating service within a 30-day period. All respiratory-related outpatient prescription drugs dispensed during this period were also captured. These drugs included those that were listed to define physician visit-initiated episodes described earlier, as well as those that are used for chronic management of COPD and other respiratory-related conditions (eg, long-acting beta-agonists and long-acting bronchodilator combined with anti-inflammatory medications). Inclusion of all respiratory-related drugs increased the possibility of capturing all relevant drug utilizations during the episode.

An episode ended after either the occurrence of a 30-day clean period in which there were no respiratory-related healthcare contacts or deaths. All patients were followed for at least 1

year from their index date until March 31, 2012 or death, whichever occurred first. All episodes that were ongoing at the end of the observation period were excluded. This study was limited to index episodes, that is, all first hospital- or ED-initiated episodes of care following the COPD diagnosis date.

## Study Measures

### Indicators of Care Pathways

The indicators of care pathways were based on all respiratory-related services received following the episode-initiating service. Specifically, binary measures of hospitalization, ED visit, GP visit, specialist visit, and outpatient prescription drug dispensation were used to define care pathways.

### Episode Cost, Duration, and Intensity

The episode cost was the sum of all respiratory-related costs incurred between the episode start and end dates. Hospital costs were estimated based on a standard methodology developed by CIHI for all Canadian provinces.[21] For the ED cost component, total annual expenditures were obtained from the Ministry of Health and total annual numbers of visits were extracted from the ED database; these were used to estimate an average cost per visit. The cost of a physician visit was the amount billed by the physician to the provincial Ministry of Health. Prescription drug costs were based on the price of the active substance plus a dispensing fee. Episode costs were adjusted for inflation using the health and personal care components of the Saskatchewan consumer price indices,[22] and expressed in 2011/12 constant dollars.

Duration was measured in days, starting from the first day of the episode-initiating service to the date the last service was received. Episode intensity was measured by the number of times the patient contacted care providers during the episode.

### Patient and Disease Characteristics

The patient and disease characteristics included in the analysis were based on the Andersen healthcare utilization model.[23] Andersen proposed that an individual's healthcare use is influenced by 3 broad groups of factors, namely predisposing, enabling, and need. The predisposing factors included in this study were sex and age group (ie, 35−54, 55−74, or 75+). The enabling factor was residence location (ie, urban or rural). Urban residents were those whose postal codes were in a census metropolitan or agglomeration area (ie, 10,000 + population). The need factors were comorbid conditions, which were measured using the Charlson index,[24] as well as by the 3 most prevalent comorbid conditions in the study cohort; including congestive heart failure (ie, yes or no), diabetes (ie, yes or no), and hypertension (ie, yes or no). These comorbid conditions were defined using *ICD-9* and *ICD-10-CA* codes,[25] and were based on diagnoses in the hospital discharge abstract and the physician billing claims data. A higher score of the Charlson index indicates greater comorbidity, and we categorized the index as 0, 1, or ≥2. We also included the fiscal year of COPD diagnosis (ie, 2007/08, 2008/09, 2009/10, or 2010/11). All variables were defined as of the index date of COPD diagnosis except for the comorbid conditions, which were defined using data from the year before the index date.

## Statistical Analysis

LCA was used to classify patients into distinct pathway groups based on healthcare services in the index episode. LCA assumes that each individual in the study belongs to one of a set of mutually exclusive and exhaustive classes.[26] We fit models to the data having between 2 and 7 classes. The Bayesian-Schwarz Information Criterion (BIC),[27] which is a penalized measure of the likelihood function, as well as entropy, a measure of the quality of class separation, was used to guide the selection of the optimal number of classes.[28] Entropy values range from 0 to 1, with values ≥0.8 often recommended as indicative of good class separation; whereas a smaller BIC for a particular model suggests that it is preferable on the basis of the trade-off between fit and parsimony. Final model selection was based on these indices, as well as the usefulness and interpretability of results.[13] The usefulness of results was assessed based on the number of individuals in each latent class, with classes of <10 individuals not being considered.

Subsequent to choosing the final model, the hospital- and ED-initiated pathways identified were described. Multinomial logistic regression models were used to test patient demographic and disease characteristics associated with pathway groups. To avoid multicollinearity between Charlson comorbidity index and the 3 most prevalent comorbid conditions in the study cohort, 2 sets of multinomial logistic regression models were conducted. The first model included patient demographics (ie, age, sex, and residence location), Charlson comorbidity index, and COPD diagnosis fiscal year as covariates. The second model included the 3 most prevalent comorbid conditions, and adjusted for patient demographics and COPD diagnosis fiscal year. Only the adjusted odds ratios (ORs) (with the 95% confidence intervals [CIs]) of the 3 most prevalent comorbid conditions were reported from the second model. Furthermore, we plotted the means (with the 95% CIs) of episode duration and healthcare contacts by pathway groups. The plots helped to examine the variations in these episode characteristics by pathway groups. We also described the sequence in which patients contacted care providers, focusing on the most frequent patterns in the study cohort. We calculated the percentage of deaths within the most frequent sequence in each care pathway. Finally, we used $\chi^2$ statistics to test for differences in outcomes (ie, costs and mortality) between care pathways using a model-based method.[29] The method empirically derives and summarizes the class-dependent density functions of outcomes with categorical, continuous, or count distributions.

SAS version 9.3 (SAS Institute Inc, Cary, NC) was used for the descriptive analyses and data manipulation. Mplus version 7.2 (Muthén & Muthén, Los Angeles, CA) was used to perform the LCA.

# RESULTS

## Cohort Selection

A total of 12,543 COPD patients were identified between April 1, 2007 and March 31, 2011. After exclusion criteria were applied (ie, previous healthcare utilization with a COPD diagnosis within a 5-year look-back period [38.0 %], and not having continuous provincial health insurance coverage [5.4%]) the remaining 7099 individuals were eligible for study inclusion. During follow-up, 2659 individuals experienced at least 1 COPD episode of care, which resulted in a total of 5348 episodes. We excluded a total of 156 (2.9%) episodes because they were still ongoing at the end of study period. Further, since the study focused on moderate-to-severe exacerbations, we excluded all those whose episodes were initiated by a physician visit (1332; 50.1%). The final cohort (n = 1327) was comprised

of all individuals whose index episode was initiated by a hospitalization (n = 963; 72.6%) or an ED visit (n = 364; 27.4%). Separate analyses were conducted for the 2 groups.

## Latent Class Model Selection

The BIC value was smallest for the 3-class model in both the hospital- and ED-initiated groups. Entropy was highest (0.91) for the 3-class model among individuals with hospital-initiated episodes, but was highest (0.78) for the 5-class model among the individuals with ED-initiated episodes. However, the 5-class model had at least 1 class comprised of <10 individuals, rendering it not useful for further analysis. Given that the improvement in entropy of the 5-class model over the 3-class model among the ED-initiated episodes was only marginal (0.04), we selected the 3-class model for both groups.

## Characteristics of Care Pathways

Table 1 summarizes the results of the healthcare pathways derived from LCA models. Among individuals with a hospital-initiated episode, Pathway 1 (7.2%) was comprised of those who had a high probability of ED visit(s), GP visit(s), and specialist visit(s) after their initial hospital discharge. Also, they had a high probability of having another hospitalization during the same episode. Pathway 2 (35.6%) was comprised of individuals who had a high probability of follow-up visit(s) to GPs and outpatient drug dispensations after their episode-initiating hospitalization. The majority of individuals were in Pathway 3 (57.2%); they had a lower probability of having any follow-up contacts after their episode-initiating hospital discharge.

Similarly, among individuals with an ED-initiated episode (Table 1), those in Pathway 1 (27.2%) had a higher probability of hospitalization, GP and specialist visits, and outpatient drug dispensations following their initial ED visit. The majority of individuals, who belonged to Pathway 2 (48.6%) had a lower probability of having any follow-up utilization after their initial ED discharge. Pathway 3 (24.2%) was comprised of individuals who had a higher probability of follow-up visit(s) to GPs and outpatient drug dispensations after their episode-initiating ED visit.

## Patient Characteristics and Care Pathways

Table 2 shows the results of the multinomial logistic regression models, which examined the association between pathway group membership, and patient demographic and comorbidity characteristics. Among individuals with a hospital-initiated episode, those in the 55 to74 years' age group were more likely to be in Pathway 1 compared with Pathway 3 (OR = 2.08, 95% CI 1.11–3.90). Individuals in Pathway 2 were more likely to be female compared to individuals in Pathway 3 (OR = 1.58, 95% CI 1.20–2.09). Also, individuals with a Charlson comorbidity index score of 1 (OR = 0.66, 95% CI 0.47–0.95) or ≥2 (OR = 0.46, 95% CI 0.33–1.59) were less likely to be in care Pathway 2 compared to care Pathway 3. Among individuals with an ED-initiated episode, those in Pathway 3 were less likely to be female (OR = 0.55, 95% CI 0.30–0.99), or to have a Charlson comorbidity score ≥2 (OR = 0.32, 95% CI 0.11–0.93) compared with individuals in Pathway 2.

Among individuals with a hospital-initiated episode, those in Pathway 1 had a significantly higher odds of congestive heart failure (OR = 1.31, 95% CI 1.04–1.65) compared with those in Pathway 3 (Table 2). Also, individuals in Pathway 2 had a lower odds of hypertension (OR = 0.59, 95% CI 0.37–0.92) compared with those in Pathway 3. Among individuals with an ED-initiated episode, those in Pathway 1 had significantly higher odds of diabetes (OR = 1.33, 95% CI 1.02–1.74) and hypertension (OR = 1.44, 95% CI 1.04–2.00) compared with those in Pathway 2.

## Episode Duration, Care Contacts, and Care Sequence by Care Pathways

Figure 1 describes the mean (95% confidence intervals) duration of episodes and mean healthcare contacts by care pathways. Among individuals with a hospital-initiated episode, those in Pathway 1 had the longest episode duration as well as

**TABLE 1.** Item-response Probabilities Estimated From Latent Class Analysis to Identify Care Pathways by Episode Initiation

| | Pathway 1 (n = 69) | Pathway 2 (n = 343) | Pathway 3 (n = 551) |
|---|---|---|---|
| **Hospital-initiated Episodes** | | **λ (standard error)** | |
| ED visit | 1.00 (0.00) | 0.01 (0.01) | 0.01 (0.01) |
| GP visit | 0.71 (0.07) | 0.82 (0.02) | 0.32 (0.03) |
| Specialist visit | 0.91 (0.05) | 0.46 (0.03) | 0.35 (0.02) |
| Drug dispensation | 0.44 (0.08) | 0.94 (0.07) | 0.00 (0.00) |
| Another hospitalization | 0.57 (0.08) | 0.08 (0.02) | 0.00 (0.01) |
| | **Pathway 1 (n = 99)** | **Pathway 2 (n = 177)** | **Pathway 3 (n = 88)** |
| **Emergency Department-initiated Episodes** | | **λ (standard error)** | |
| Hospitalization | 0.91 (0.19) | 0.39 (0.05) | 0.00 (0.00) |
| GP visit | 0.73 (0.05) | 0.19 (0.06) | 0.65 (0.07) |
| Specialist visit | 0.70 (0.05) | 0.24 (0.04) | 0.25 (0.14) |
| Drug dispensation | 0.72 (0.07) | 0.00 (0.00) | 0.83 (0.13) |
| Another ED visit | 0.23 (0.04) | 0.02 (0.02) | 0.12 (0.06) |

λ = item-response probability that the healthcare service was used by individuals in the pathway, ED = emergency department, GP = general practitioner.

**TABLE 2.** Results of Multinomial Logistic Regression Predicting Patient Care Pathway Membership

| | Hospital-initiated Episodes (n = 963) | | Emergency Department-initiated Episodes (n = 364) | |
|---|---|---|---|---|
| | Pathway 1* | Pathway 2* | Pathway 1† | Pathway 3† |
| | Odds ratio (95% Confidence Interval) | | | |
| Age, y | | | | |
| 35–54 | 2.03 (0.82– 5.03) | 0.84 (0.52–1.37) | 0.88 (0.36–2.12) | 1.01 (0.39–2.63) |
| 55–74 | 2.08 (1.11–3.90)‡ | 1.17 (0.87–1.54) | 0.93 (0.53–1.63) | 1.23 (0.65–2.33) |
| 75+ (Reference) | | | | |
| Sex | | | | |
| Female | 0.85 (0.47–1.54) | 1.58 (1.20–2.09)‡ | 1.43 (0.85–2.40) | 0.55 (0.30–0.99)‡ |
| Male (Reference) | | | | |
| Residence location | | | | |
| Urban | 1.85 (0.90–3.81) | 1.19 (0.87–1.63) | 0.75 (0.36–1.56) | 1.91 (0.67–5.46) |
| Rural (Reference) | | | | |
| Charlson comorbidity index | | | | |
| 0 (Reference) | | | | |
| 1 | 0.44 (0.18–1.07) | 0.66 (0.47–0.95)‡ | 1.53 (0.68–3.44) | 0.36 (0.11–1.16) |
| ≥2 | 0.83 (0.43–1.59) | 0.46 (0.33–0.65)‡ | 0.51 (0.23–1.16) | 0.32 (0.11–0.93)‡ |
| COPD diagnosis fiscal year | | | | |
| 2007/08 (Reference) | | | | |
| 2008/09 | 0.96 (0.41–2.25) | 0.99 (0.64–1.53) | 0.82 (0.37–1.79) | 1.10 (0.51–2.40) |
| 2009/10 | 0.94 (0.40–2.22) | 0.89 (0.57–1.39) | 1.29 (0.61–2.73) | 0.50 (0.20–1.26) |
| 2010/11 | 0.69 (0.32–1.48) | 0.96 (0.66–1.39) | 1.83 (0.95–3.54) | 0.97 (0.46–2.06) |
| Congestive heart failure§ | | | | |
| No (Reference) | | | | |
| Yes | 1.31 (1.04–1.65)‡ | 0.99 (0.67–1.47) | 0.86 (0.39–1.86) | 1.32 (0.45–3.88) |
| Diabetes§ | | | | |
| No (Reference) | | | | |
| Yes | 0.63 (0.28–1.42) | 0.76 (0.51–1.13) | 1.33 (1.02–2.74)‡ | 0.73 (0.22–2.45) |
| Hypertension§ | | | | |
| No (Reference) | | | | |
| Yes | 0.84 (0.45–1.56) | 0.59 (0.37–0.92)‡ | 1.44 (1.04–2.00)‡ | 1.42 (0.77–2.64) |

COPD = chronic obstructive pulmonary disease.
* Reference group was pathway 3.
† Reference group was pathway 2.
‡ Significant at $\alpha = 0.05$.
§ The odds ratios (95% confidence intervals) reported were adjusted for age, sex, residence location, and COPD diagnosis fiscal year in separate multinomial logistic regression model.

the highest number of healthcare contacts. Similarly, among individuals with an ED-initiated episode, those in Pathway 1 had the longest episode duration and highest number of healthcare contacts. However, although individuals in Pathway 3 had longer duration than those in Pathway 2, the number of healthcare contacts in the 2 pathways was similar.

Among individuals with a hospital-initiated episode, almost one-quarter of those in Pathway 1 had a specialist visit following hospital discharge, followed by ED and specialist visits (Figure 2A). Among individuals in Pathway 3, 41.2% did not have follow-up care after hospital discharge. Further analysis indicated that only 20.3% of the individuals who followed this sequence died during the episode (Figure 3A). For individuals with an ED-initiated episode, 18.2% of those in Pathway 1 had a hospitalization following the ED discharge followed by specialist visit; and close to one-fifth of those in Pathway 3 did not have any follow-up care, although they were discharged from the ED and remained alive throughout the episode (Figure 2B). Of the 57 people in Pathway 2 who did not have any follow-up care (Figure 2B), only 14.0% of them died during the episode (Figure 3B).

## Comparison of Healthcare Outcomes between Care Pathways

Table 3 shows the results for the tests of differences in healthcare outcomes between pathways for both hospital- and ED-initiated episodes. Among individuals with a hospital-initiated episode, those in Pathway 1 had a higher mean cost ($29,480; SD = 54,907) than those in Pathway 2 ($9817; SD = 21,865), and Pathway 3 ($10,619; SD = 21,042) ($P = 0.049$). A higher percentage (18.0%) of individuals in Pathway 3 died during their episode compared with individuals in Pathway 1 (15.9%) and Pathway 2 (6.1%) ($P < 0.001$).

Among individuals with an ED-initiated episode, those in Pathway 1 had higher mean cost ($9204; SD = $10,019) than those in Pathway 2 ($3493; SD = $5279) and Pathway 3 ($943;

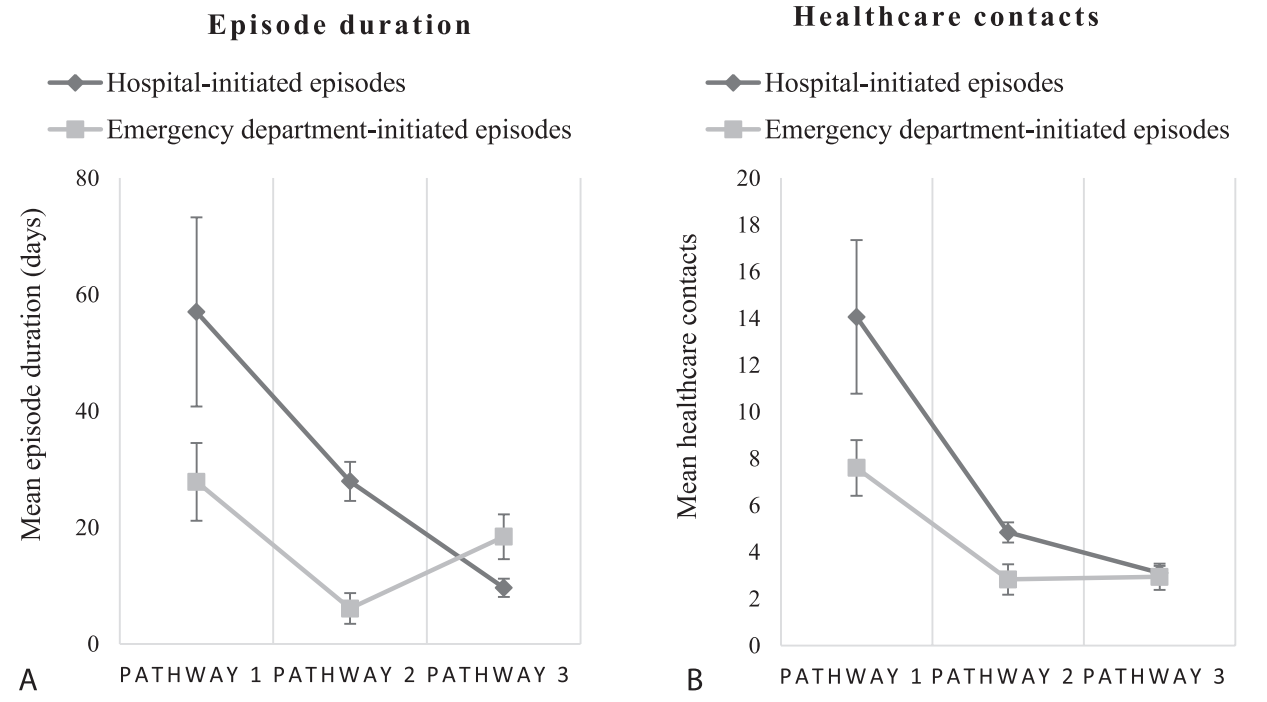


**FIGURE 1.** Mean (95% confidence intervals) episode duration (A) and care contacts (B) by care pathway.

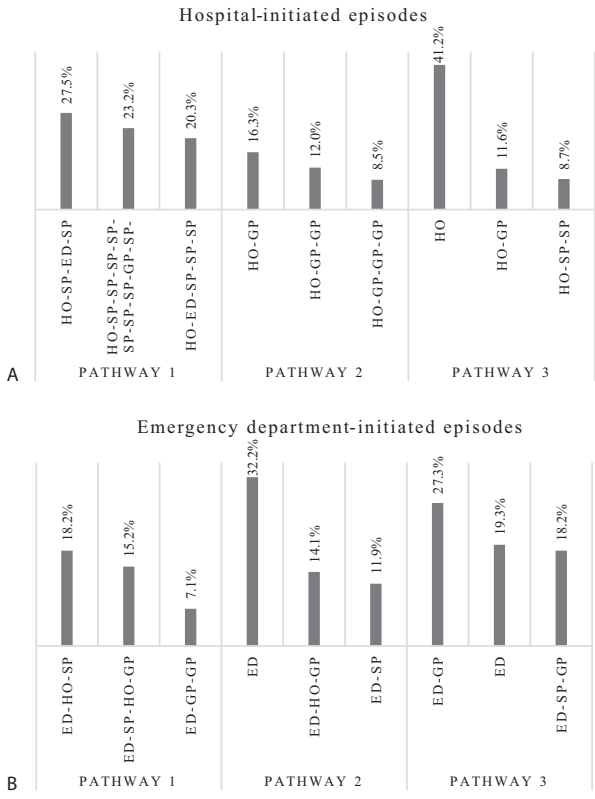


**FIGURE 2.** Frequent healthcare contact sequences by care pathway for hospital-initiated (A) and emergency department-initiated (B) episodes.

SD = $2992) ($P < 0.001$). Higher percentage (10.7%) of individuals in Pathway 2 died during their episode compared with individuals in Pathway 1 (10.1%) and Pathway 3 (0.0%) ($P = 0.006$).

## DISCUSSION

In this study, we applied a model-based approach to characterize healthcare pathways for COPD patients, focusing on hospital- and ED-initiated episodes of care. Understanding the pathways that these patients follow after they are discharged from the acute care setting is important for identifying opportunities for redesigning healthcare delivery to improve quality of care and lower cost.[6] This population-based study uniquely presents the relationship between pathways and healthcare outcomes.

Three distinct care pathways were identified among individuals with a hospital-initiated episode. Individuals in these pathways differed in terms of the health services they utilized, as well as the sequence in which they contacted care providers. A small group of individuals (7.2%) made repeated use of a wide variety of healthcare services during their episode, which resulted in their cost being about 3 times higher than the pathway group with the lowest cost. Similarly, 3 distinct pathways were identified among the individuals with an ED-initiated episode. More than one-quarter of individuals whose episode were initiated by an ED visit used multiple services, and their healthcare costs were approximately 10 times higher than the pathway group with the lowest cost.

Analysis of the duration, intensity, and sequence of healthcare contacts provides a clear description of the care processes experienced by individual patients during COPD exacerbations. Particularly, the sequence analysis was useful for examining postdischarge follow-up care. Information on the sequence in which patients contacted care providers may point at deviations from recommended care practices. For example, it is recommended that patients treated for COPD exacerbations should have a follow-up visit to a primary care provider between 2 to 4

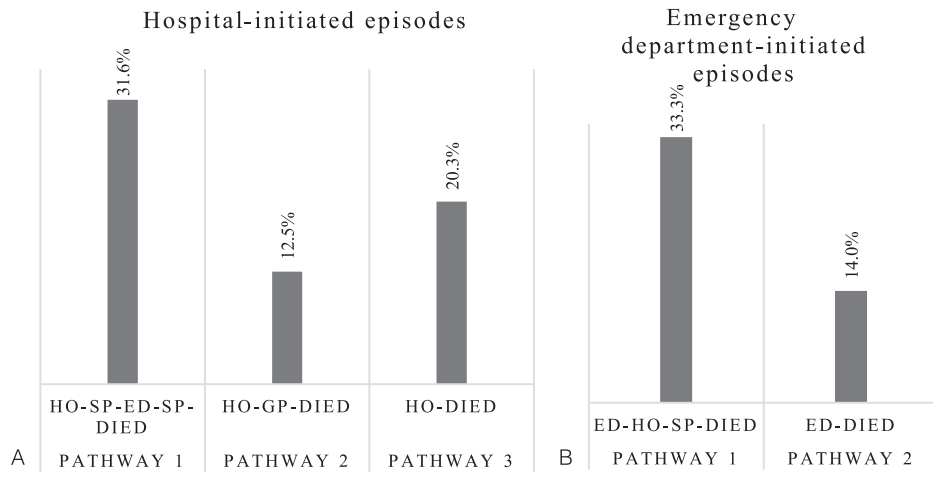


**FIGURE 3.** Percentage of individuals who died in the most frequent healthcare contact sequences for hospital-initiated (A) and emergency department-initiated (B) episodes.

weeks after an inpatient acute care discharge.[5] Our results indicate that this recommendation is not closely followed. We found that close to 19% of the entire study cohort were discharged from either ED or hospital and remained alive during the episode, but did not have any follow-up contacts with the healthcare systems. Although these patients represented a small percentage of the cohort, quality of care improvement programs could be targeted toward them to fully align COPD treatment with recommended care practice.

A previous result[30] showed that the way in which substance abuse episodes were initiated (eg, inpatient hospitalization) was associated with outcomes such as cost. Our study of a cohort of newly diagnosed COPD patients indicate that considerable heterogeneity exists in healthcare costs even among individuals whose episodes of care were initiated by the same healthcare service, and these variations may be partly explained by patient demographic and disease characteristics. Previous studies identified age[13] and comorbidities[31] as predictors of healthcare utilization. We found that patient age, gender, and comorbid conditions were associated with healthcare pathways. Although these characteristics are not modifiable, they are useful for identifying patients who might follow either complex pathways or pathways, which are not aligned with recommended care practices, especially in subsequent episodes.

The study has some limitations. First, a common limitation of studies that have used administrative health data to construct episodes of care is the inability to consistently distinguish between scheduled and unscheduled healthcare visits. Although the information about whether or not a healthcare visit was scheduled might be useful for assessing the quality of care, it is not routinely collected in some databases.[32] A second potential limitation of the study is that we only considered a clean period of 30 days to distinguish one episode from another, although this is a common approach to defining episodes of care.[30] Lastly, we used per diem rates and charges to estimate some cost components. However, hospitalization, which was the major component of episode costs, was based on a standard methodology developed by CIHI to reflect actual resource utilization.

Despite these limitations, this study demonstrates a practical approach for describing healthcare pathways. By linking various administrative health databases, our study describes patient journeys covering the primary, emergency, and acute care settings. This is the first study to provide such a comprehensive description of pathways, an important information for anticipating and allocating resources to meet the needs of this patient sub-group. This is particularly relevant because this patient subgroup is expected to increase in the

**TABLE 3.** Characteristics of Health Outcomes Overall and By Care Pathways

| **Hospital-initiated Episodes** | **Overall (n = 963)** | **Pathway 1 (n = 69)** | **Pathway 2 (n = 343)** | **Pathway 3 (n = 551)** | ***P**** |
|---|---|---|---|---|---|
| Costs, mean (SD) | 11373.3 (24531.3) | 29479.7 (54907.9) | 9817.1 (21865.9) | 10619.1 (21042.9) | 0.044 |
| Death during episode (%) | 13.6 | 15.9 | 6.1 | 18.0 | <0.001 |
| **Emergency Department-initiated Episodes** | **Overall (n = 364)** | **Pathway 1 (n = 99)** | **Pathway 2 (n = 177)** | **Pathway 3 (n = 88)** | ***P*** |
| Costs, mean (SD) | 4557.5 (7170.4) | 9204.1 (10019.2) | 3493.3 (5279.7) | 943.2 (2992.2) | <0.001 |
| Death during episode (%) | 8.0 | 10.1 | 10.7 | 0.0 | 0.006 |

COPD = chronic obstructive pulmonary disease, SD = standard deviation.

* Differences between pathway groups were tested with the $\chi^2$ statistics, using the Auxiliary option of the Variable command in Mplus. We specified (DCON) for cost and (DCAT) for death. These options produce the results for the method proposed by Lanza et al.[31]

future, placing even higher economic burden on the healthcare system.[7]

In conclusion, the LCA approach identified the major pathways patients with COPD followed through a provincially insured healthcare system during episodes of the disease exacerbation. Patients who followed complex pathways could benefit from case management interventions to streamline their journeys through the healthcare system. The minority of patients whose pathways were not consistent with the recommended follow-up care should be further investigated to fully align COPD treatment in the province with recommended care practices. Our modeling approach could be applied to other resource-intensive health conditions, such as hypertension and diabetes.

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