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Does using information on long-standing chronic conditions improve predictive performance of the ACG case-mix system?

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Xiaotong Huang, MPH
Ruth Lavergne, PhD
Sandra Peterson, MSc
Megan Ahuja, MPH
Kimberlyn McGrail, PhD

THE UNIVERSITY OF BRITISH COLUMBIA

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Centre for Health Services and Policy Research
School of Population and Public Health
University of British Columbia
201–2206 East Mall
Vancouver, BC V6T 1Z3
Email: chspr.reception@ubc.ca

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Abstract

Introduction

The Johns Hopkins Adjusted Clinical Group (ACG) System groups diagnosis codes (into aggregated diagnosis groups, or ADGs) and assigns patients to a single ACG based on all diagnoses, typically from a one year period. It is plausible that long-standing chronic conditions may not be in diagnosis codes each year.

Objectives

Determine if attaching chronic disease registry data improves the performance of a case-mix system in predicting total health care spending and acute care expenditure, compared to using diagnoses from a single year of data only.

Methods

We used 12 years of administrative data to build a chronic disease registry. We used two-part models to determine whether adding diagnosis codes for known chronic conditions from the registry improves the predictive performance of the ACG System on next-year healthcare costs compared to diagnosis codes from a single year of data.

Results

We find that ADGs assigned based on a chronic disease registry changed marginally, but did not improve cost prediction.

Conclusion

Researchers can feel confident using case-mix systems with a single year of data to predict health care costs.

Note

This report is a subsequent analysis to an article published in *Medical Care:*

> Huang X, Peterson S, Lavergne R, Ahuja M, McGrail KM. *Predicting the cost of health care services: A comparison of case-mix systems and comorbidity indices that use administrative data.* Medical Care. 58(2): 114-119. 2020.

The article compares predictions of next-year health care services costs across four case-mix systems, including: The Johns Hopkins Adjusted Clinical Groups (ACG) System, the Elixhauser Comorbidity Index, the Charlson-Deyo Comorbidity Index, and the Canadian Institute for Health Information (CIHI) population grouper. All of these case-mix systems used one year of health care services use to predict next-year costs, and the main analytical output can be found in Appendix A of this report.

This report looks at how the addition of chronic disease registry information could improve next-year costs using the Johns Hopkins ACG System.

Introduction

Case-mix systems are used to classify patients with similar health conditions and/or similar health care service use patterns into groups, to help set rates under capitation and/or predict health resource use and mortality for research purposes.[1-3] The Johns Hopkins Adjusted Clinical Group (ACG) System is one of the most widely-used and extensively-validated case-mix systems in Canada.[4,5] This system relies on diagnosis information from billing records, typically a single year, to classify patients into distinct case-mix groups.[6]

Existing literature shows that identifying chronic conditions using only billing data leads to underestimates of prevalence, and this can be made worse by using only one year of data.[7,8] Chronic disease registries are built as a way to identify chronic disease using multiple sources of data (e.g. billing data and pharmaceutical data).[9] In the absence of other diagnostic information, increasing the time frame to collect chronic disease diagnoses could improve sensitivity of identifying chronic disease.[10] An alternative could be to expand the time frame for diagnoses included in case-mix systems, for example to two years. While this might improve the collection of chronic disease information, it would also overstate the presence of acute events. For example, an acute event in year one may well resolve and imply no need for health care in year two.

Within British Columbia (BC), Canada, physician billing records typically include one diagnostic code per visit and records of acute hospital stays or day surgery contain up to 25 diagnoses and case mix systems are applied using one year of diagnoses. In this study we explore whether using information on long-standing chronic conditions from previous years of administrative data improves predictive performance of the ACG System on health care cost, compared to using diagnoses from a single year of data only.

Methods

Setting

This paper used data from BC and builds on previous analyses comparing case-mix systems and comorbidity indices.[11]

Study population

Our study population consists of all BC residents who were 19 years of age or older in 2012/13. We ensured they were registered to receive health care for 275 days or more in both 2012/13 and 2013/14.

Data sources

We used administrative health care data from Population Data BC from 1999/2000 to 2011/12 to collect diagnosis codes and classify patients into Aggregated Diagnosis Group (ADG) and ACG case-mix groups. We used the following data sources:

- The Medical Services Plan (MSP) data consists of diagnoses (International Classification of Diseases (ICD)-9 codes) from all practitioners who submit claims (both fee-for-service and shadow billings/encounter claims), and payment information from all fee-for-service physicians and midwives in BC. Physician claims information was used for chronic disease and case-mix classification (diagnoses) and contributed to calculations of total health care costs (amount paid).
- Discharge Abstracts Database (DAD)/hospital separations data contains all hospital inpatient and day surgery separations. Each record includes up to 25 ICD-10-CA codes indicating the principal reason for admission and other comorbidities and conditions that arise after admission.[13] We used diagnosis information from each separation for chronic disease and case-mix classification. The Resource Intensity Weight field indicates the intensity of resource use (relative costs) and was used to calculate acute and total health care costs.[14]
- PharmaNet data includes all community-based prescriptions filled (with limited exception for those federally covered) and contributed to calculations of total health care costs.[15]
- Consolidation file (patient demographics) data includes information on age, sex, neighbourhood socioeconomic status (income quintile), and region of residence of all BC residents who are registered to receive health care.[16] These data were used for case-mix classification and demographic descriptions.

Chronic disease registry

Administrative data from 1999/2000 to 2011/12 were used to build a chronic disease registry (CDR). We focus on chronic conditions that qualify for incentive payments within BC, as these were identified by policy makers as high prevalence and/or high impact conditions. We identified patients with one inpatient and/or two outpatient codes within a rolling two year period for any of the following chronic conditions: diabetes; congestive heart failure; hypertension; chronic obstructive pulmonary disease (COPD); asthma; chronic respiratory conditions other than COPD and asthma; cerebrovascular disease; ischemic heart disease; chronic neurodegenerative disease; chronic liver disease; and chronic kidney disease (renal failure).[9,17,18] Once individuals met the inclusion criteria for any of these conditions, we included ICD codes corresponding to the diagnosed condition in the annual collected diagnoses in 2012/13 (Appendix B), supplementing diagnoses that appear on records of health care services use in that year.

Case-mix system

The ACG System categorizes diagnoses from physician and hospital data into 34 ADGs based on severity, expected duration, and likelihood of recurrence, and then assigns an ACG category to each individual as a combination of ADGs, age, and sex[4,6] (Appendix C). Two versions of ACG/ADGs were created using John Hopkins ACG software (V11.1) for the subsequent statistical analyses. One used the collected diagnoses in 2012/13 only; the other used diagnoses in 2012/13 plus additional ICD 9 codes for all chronic conditions for individuals indicated in our CDR, as described above.

Statistical analysis

We assessed the prediction performance on next-year (fiscal year 2013/14) total health care costs and acute care costs, comparing the two versions of case-mix variables. Before modeling, each cost was truncated at the 99th percentile within age and sex groupings to prevent outliers from overly influencing the analysis. All independent variables, including case-mix variables, age (5-year age groups) and sex were included as categorical variables with dummy variables for each discrete value.

The distribution of our outcome is highly right-skewed, common in health care spending as a subset of the population is clustered at zero. It is for this reason that we used two-part models.[19,20] The two-part models included: (1) a logistic regression to predict the probability of having non-zero next-year healthcare costs, and (2) a generalized linear model with gamma distribution and a log link based on people with positive costs to predict next-year total costs.[11] We ran the model using the two versions of case-mix system indicators separately, with and without CDR-generated diagnoses included. Three models were run for each version, (1) demographics only, (2) demographics + set of dummy variables for 34 ADG categories, and (3) demographics + dummy variables for ACG categories. We then calculated and reported the coefficient of determination (R^2), root mean squared error (RMSE), and mean absolute error (MAE) using the predicted next-year cost and the actual next-year cost to assess the model performance with and without the addition of CDR-generated diagnoses, a common approach for comparing performance of case-mix systems.[20,21]

Results

The study population included 3,478,091 adult BC residents (Table 1). As of 2011/12, 22.03% of the study population had one chronic disease diagnosis within the CDR, and a further 17.23% had two or more. In 2012/13, four in five individuals (79.25%) had no difference in total assigned number of ADGs using only annually-collected diagnosis codes compared with annual diagnosis codes plus CDR-generated diagnoses. 17.34% had one more ADG, and less than 4% had an increase of two or more (Table 2).

The chronic conditions reflected in the CDR but not in 2012/13 data tended to be less complex. Hypertension accounted for 21.92% of these diagnoses, asthma for 12.19%, and ischemic heart disease for 12.10%. (Appendix D)

We assessed the model performance on next-year total costs and acute care costs by comparing R^2, RSME, and MAE (Table 3). For all models, all the measures of model fit remain almost the same after including the CDR-based diagnosis codes. In next-year total cost, R^2 values were 0.2 for both ACG models (with/without the CDR-based diagnoses). RMSE slightly decreased from 4,368 to 4,366, and MAE slightly decreased from 1,946 to 1,943 after including CDR-based diagnoses code from previous years. Retaining codes for known chronic conditions results in almost no differences in model performance. Using information on long-standing chronic conditions from previous years of administrative data does not improve predictive performance of the ACG system on health care cost.

Table 1. Study population demographics, 2012/13

Age group	Frequency & percentage
19-29 years	589,616 (16.95%)
30-39 years	555,562 (15.97%)
40-49 years	644,813 (18.54%)
50-59 years	687,464 (19.77%)
60-69 years	519,797 (14.94%)
70-79 years	289,929 (8.34%)
80+ years	190,910 (5.49%)
Sex	
Female	1,785,748 (51.24%)
Male	1,692,343 (48.66%)
Use of health services	
Non-users (total health care cost=0)	493,646 (14.19%)
Users below average	2,167,920 (62.33%)
Users above average	816,525 (23.48%)
In year mean costs	**Dollars & standard deviation (SD) or interquartile range (IQR)**
Total annual cost of physician care	$643 (961)
Total ann. cost of acute hosp. care	$469 (2,576)
Total annual cost of prescriptions	$663 (1,359)
Total health care spending	$1,960 (4,345)
In year median costs	
Total health care spending	$556 (199-1,807)
Next year mean costs	
Total health care spending	$2,080 (4,866)
Total annual cost of physician care	$647 (981)
Total ann. cost of acute hosp. care	$567 (3,081)
Total annual cost of prescriptions	$667 (1,392)
Next year median costs	
Total health care spending	$555 (115-1,818)

Table 2. Distribution of chronic conditions and ADGs across the adult BC population (n= 3,478,091), 2012/13

	Number of chronic conditions recorded in the CDR as of 2011/12 (% BC residents in each category)	Number of ADGs based on annual collected diagnoses (% BC residents in each category)	Number of ADGs based on annual collected diagnoses plus CDR (% BC residents in each category)	Difference in ADG counts after inclusion of CDR (% BC residents in each category
0	2,112,393 (60.73%)	584,242 (16.8%)	497,705 (14.31%)	2,756,411 (79.25%)
1	766,339 (22.03%)	457,628 (13.16%)	452,518 (13.01%)	603,273 (17.34%)
2	316,650 (9.10%)	482,523 (13.87%)	472,253 (13.58%)	102,955 (2.96%)
3	151,017 (4.34%)	454,899 (13.08%)	450,930 (12.96%)	14,011 (0.40%)
4	75,373 (2.17%)	393,687 (11.32%)	397,511 (11.43%)	1,344 (0.04%)
5	35,559 (1.02%)	318,584 (9.16%)	329,000 (9.46%)	92 (0%)
6+	20,760 (0.60%)	786,528 (22.61%)	878,174 (25.25%)	5 (0%)

Note: CDR indicates chronic disease registry; ADG, aggregated diagnosis group.

Table 3. R^2, RMSE and MAE of the two-part models for total and acute costs

Comparison of models using different case-mix systems, predicting next-year total costs (R^2, RMSE, MAE)
2-part model, logistic + GLM (distribution=gamma, link=log)

	R^2	*RMSE*	*MAE*
Baseline			
Age+sex	0.08	4,663	2,242
Original			
Age+sex+34ADG	0.16	4,808	2,027
Age+sex+ACG	0.20	4,368	1,946
With CDR			
Age+sex+34ADG	0.17	4,663	2,001
Age+sex+ACG	0.20	4,366	1,943

Comparison of models using different case-mix systems, predicting next-year acute costs (R^2, RMSE, MAE)
2-part model, logistic + GLM (distribution=gamma, link=log)

Baseline			
Age+sex	0.05	3,006	1005
Original			
Age+sex+34ADG	0.09	2,940	943
Age+sex+ACG	0.09	2,940	939
With CDR			
Age+sex+34ADG	0.09	2,941	944
Age+sex+ACG	0.09	2,943	940

Note: GLM indicates generalized linear model; CDR, chronic disease registry; R^2, coefficient of determination; RMSE, root mean squared error; MAI, mean absolute error; ADG, aggregated diagnosis group; ACG, adjusted clinical group.

Discussion

Retaining diagnoses of chronic diseases in all subsequent years changed the assignment of ADGs for 20.75% of the population, but did not improve model performance. This provides some reassurance that the diagnostic information captured within one year of data are sufficient to understand chronic disease morbidity, at least in the context of predicting next-year health spending.

Results also highlight that resources required to manage and treat chronic conditions are likely to vary substantially year to year. The diagnosis codes captured in the CDR but not 2012/13 tended to be for less complex conditions (e.g. hypertension), which implies that the diagnoses captured in a given year truly reflect the conditions driving care in that year. It is plausible that for some chronic conditions (e.g. asthma) additional physician visits and treatment are concentrated at the time of diagnosis, but after the initial diagnosis additional costs are stable. In the event the condition led to hospitalization or required focused management this condition would once again be captured in that year's diagnosis codes. Therefore, despite the literature cautioning researchers in identifying chronic disease using one year of administrative data alone,[7,8,10] it appears that any limitations related to estimating prevalence do not affect the performance of predicting next year costs.

These analyses are limited by not having a separate source of information that could describe true underlying health status of individuals involved. Our assessment of need for care is inevitably intertwined with care received and diagnoses attached to that care. This is the case for any observational study, and will matter to the extent that variations in practice for similar patients are linked to patterns of diagnosis for those patients. This limitation is likely to increase heterogeneity within case mix groupings but should have limited effect on the specific analyses undertaken here.

Conclusion

Adding diagnosis information on chronic conditions from previous years and including this information for a subsequent year into the John Hopkins ACG case-mix system, resulted in small changes to the assignment of ADGs but did not change the performance of predictive cost models using those ACG/ADGs. Ultimately, the choice of approach should be influenced by the intent of the analysis, recognizing the pros and cons of including all chronic disease information from previous years' diagnoses. In contexts where the goal of analysis is to understand or predict health care use (and not assign individual chronic disease diagnoses) one year of diagnosis information appears to be sufficient.

References

1. Charlson ME, Pompei P, Ales KL, MacKenzie CR. *A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation*. J Clin Epidemiol. 1987 Jan 1;40(5):373–83.

2. Elixhauser A, Steiner C, Harris DR, Coffey RM. *Comorbidity Measures for Use with Administrative Data*. Med Care. 1998 Jan;36(1):8-27. doi: 10.1097/00005650-199801000-00004.

3. Weiner JP, Starfield BH, Steinwachs DM, Mumford LM. *Development and Application of a Population-Oriented Measure of Ambulatory Care Case-Mix*. Med Care. 1991;29(5):452–72.

4. Reid RJ, MacWilliam L, Verhulst L, Roos N, Atkinson M. *Performance of the ACG Case-Mix System in Two Canadian Provinces.* Med Care. 2001;39(1):86–99. doi: 10.1097/00005650-200101000-00010

5. Reid RJ, Roos NP, MacWilliam L, Frohlich N, Black C. *Assessing Population Health Care Need Using a Claims-based ACG Morbidity Measure: A Validation Analysis in the Province of Manitoba*. Health Serv Res. 2002;37(5):1345–64. doi: 10.1111/1475-6773.01029

6. The Johns Hopkins University. The Johns Hopkins ACG System: Excerpt from Version 11.0 Technical Reference Guide [Internet]. 2014. Available from: *https://www2.gov.bc.ca/assets/gov/health/conducting-health-research/data-access/johns-hopkins-acg-system-technical-reference-guide.pdf*

7. Lix L, Yogendran M, Burchill C, Metge C, McKeen N, Moore D, et al. Defining and Validating Chronic Diseases: An Administrative Data Approach [Internet]. 2006. Available from: *http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.467.1600&rep=rep1&type=pdf*

8. Orueta JF, Nuño-Solinis R, Mateos M, Vergara I, Grandes G, Esnaola S. *Monitoring the prevalence of chronic conditions: which data should we use?* BMC Health Serv Res. 2012;12(1):365.

9. Chronic Disease Information Working Group. *BC Chronic Disease and Selected Procedure Case Definitions*. Victoria, BC: BC Ministry of Health; 2015.

10. Wilchesky M, Tamblyn RM, Huang A. *Validation of diagnostic codes within medical services claims*. J Clin Epidemiol. 2004 Feb;57(2):131–41. doi: 10.1016/S0895-4356(03)00246-4

11. Huang X, Peterson S, Lavergne R, Ahuja M, McGrail KM. *Predicting the cost of health care services: A comparison of case-mix systems and comorbidity indices that use administrative data*. Medical Care. 2020;58(2): 114-119. doi: 10.1097/MLR.0000000000001247

12. British Columbia Ministry of Health [creator]. Medical Services Plan (MSP) Payment Information File. Data Extract. MOH (2011): Population Data BC [publisher]; 2011. Available from: *https://www.popdata.bc.ca/data*

13. Canadian Institute for Health Information [creator]. Discharge Abstract Database (Hospital Separations) [Internet]. Data Extract. MOH (2011): Population Data BC [publisher]; 2011. Available from: *https://www.popdata.bc.ca/data*

14. Manitoba Centre for Health Policy. Resource Intensity Weights (RIWTM) [Internet]. 2009 [cited 2020 Jan 22]. Available from: *http://mchp-appserv.cpe.umanitoba.ca/viewDefinition.php?definitionID=103807*

15. British Columbia Ministry of Health [creator]. PharmaNet [Internet]. Data Extract. MOH (2011): Data Stewardship Committee [publisher]; 2011. Available from: *https://www.popdata.bc.ca/data*

16. British Columbia Ministry of Health [creator]. Consolidation file (MSP registration & premium billing) [Internet]. Data Extract. MOH (2011): Population Data BC [publisher]; 2011. Available from: *https://www.popdata.bc.ca/data*

17. General Practice Services Committee. *Annual Report 2009/10*. General Practice Services Committee; 2010.

18. Lavergne MR, Law MR, Peterson S, Garrison S, Hurley J, Cheng L, McGrail K. *Appendix to: A population-based analysis of incentive payments to primary care physicians for the care of patients with complex disease.* CMAJ 2016 Oct 18;188(15):E375-E383. doi:10.1503/cmaj.150858

19. Diehr P, Yanez D, Ash A, Hornbrook M, Lin DY. *Methods for Analyzing Health Care Utilization and Costs*. Annu Rev Public Health. 1999;20(1):125–44. doi: 10.1146/annurev.publhealth.20.1.125

20. Jones AM. Models for Health Care [Internet]. The Oxford Handbook of Economic Forecasting. 2012 [cited 2020 Jan 22]. Available from: *https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780195398649.001.0001/oxfordhb-9780195398649-e-24*

21. Hileman G, Steel S. Accuracy of Claims-Based Risk Scoring Models [Internet]. Society of Actuaries; 2016. Available from: *https://www.soa.org/globalassets/assets/Files/Research/research-2016-accuracy-claims-based-risk-scoring-models.pdf*

Appendix A

Comparison of models predicting next-year health care costs for adult BC population using different case-mix systems (R^2, RMSE, MAE), 2-part model, logistic + GLM (distribution=gamma, link=log)

Next-year total costs

	R^2	*RMSE*	*MAE*
Age+sex	0.08	4804.65	2280.84
Age+sex+CCI (index score)	0.15	4626.45	2143.36
Age+sex+CCI (index score)+cost flag	0.16	4601.19	2094.26
Age+sex+CCI (binary variables)	0.11	5104.74	2187.37
Age+sex+CCI (binary variables)+cost flag	0.12	4947.81	2126.20
Age+sex+ECI (index score)	0.18	4549.30	2061.70
Age+sex+ECI (index score)+cost flag	0.18	4538.15	2036.23
Age+sex+ECI (binary variables)	0.04	9819.89	2229.77
Age+sex+ECI (binary variables)+cost flag	0.05	8414.43	2163.24
Age+sex+ACG	0.18	4527.94	1988.79
Age+sex+34ADG	0.16	4969.68	2070.13
Age+sex+CIHI16	0.17	4561.59	2035.43
Age+sex+CIHI239	0.20	4479.31	1970.00

Next-year physician costs

Age+sex	0.11	939.02	579.81
Age+sex+CCI (index score)	0.20	891.09	543.22
Age+sex+CCI (index score)+cost flag	0.23	878.26	524.88
Age+sex+CCI (binary variables)	0.18	919.85	546.94
Age+sex+CCI (binary variables)+cost flag	0.21	899.56	527.18
Age+sex+ECI (index score)	0.25	862.98	517.07
Age+sex+ECI (index score)+cost flag	0.26	856.72	506.43
Age+sex+ECI (binary variables)	0.18	997.16	529.66
Age+sex+ECI (binary variables)+cost flag	0.20	959.70	515.44
Age+sex+ACG	0.29	839.48	488.53
Age+sex+34ADG	0.27	879.96	489.63
Age+sex+CIHI16	0.26	858.96	505.76
Age+sex+CIHI239	0.30	837.37	489.23

Next-year pharma costs			
	R^2	*RMSE*	*MAE*
Age+sex	0.06	1462.49	761.61
Age+sex+CCI (index score)	0.15	1387.25	700.24
Age+sex+CCI (index score)+cost flag	0.16	1379.13	679.98
Age+sex+CCI (binary variables)	0.11	1504.49	711.29
Age+sex+CCI (binary variables)+cost flag	0.13	1466.83	686.83
Age+sex+ECI (index score)	0.20	1351.57	660.77
Age+sex+ECI (index score)+cost flag	0.20	1349.07	651.41
Age+sex+ECI (binary variables)	0.05	3098.78	736.13
Age+sex+ECI (binary variables)+cost flag	0.06	2633.48	706.97
Age+sex+ACG	0.19	1356.77	663.50
Age+sex+34ADG	0.16	1542.39	686.94
Age+sex+CIHI16	0.19	1355.57	658.08
Age+sex+CIHI239	0.25	1310.71	627.58
Next-year acute care costs			
Age+sex	0.02	4858.27	1332.81
Age+sex+CCI (index score)	0.04	4828.66	1020.21
Age+sex+CCI (index score)+cost flag	0.04	4829.26	1020.93
Age+sex+CCI (binary variables)	0.05	4814.52	1287.19
Age+sex+CCI (binary variables)+cost flag	0.05	4809.92	1283.26
Age+sex+ECI (index score)	0.05	4783.18	1272.01
Age+sex+ECI (index score)+cost flag	0.05	4783.18	1270.68
Age+sex+ECI (binary variables)	0.05	4839.19	1266.87
Age+sex+ECI (binary variables)+cost flag	0.05	4836.01	1264.65
Age+sex+ACG	0.05	4782.44	1266.23
Age+sex+34ADG	0.06	4775.32	1249.45
Age+sex+CIHI16	0.05	4798.86	1268.69
Age+sex+CIHI239	0.06	4765.78	1246.28

Note: ACG indicates Adjusted Clinical Group; ADG, Aggregated Diagnostic Group; CCI, Charlson Comorbidity Index; CIHI, Canadian Institute for Health Information; ECI, Elixhauser Comorbidity Index; R^2, coefficient of determination; MAE, mean absolute error; RMSE, root mean squared error; GLM, generalized linear model. Table adapted from Table 2 in Huang X, et al. Predicting the cost of health care services: A comparison of case-mix systems and comorbidity indices that use administrative data. Medical Care. 2020;58(2): 114-119.[11]

Appendix B

ICD-9 and ICD-10 codes of chronic conditions included in the chronic disease registry (CDR)

Condition	ICD-9	ICD-10	Exclusions
Diabetes mellitus	250	E10-E14	Disregard occurrences of ICD-9 250 or ICD-10-CA E10-14 occurring 150 days before or 90 days after a delivery[9]
Hypertension	401-405	I10-I15	
Congestive heart failure	428	I50	
Chronic obstructive pulmonary disease	491, 492, 494, 496	J41-J44, J47	
Chronic kidney disease (renal failure)	582, 583, 584, 585, 586, 587, 589	N01-N07, N18, N19, N26, N27	
Chronic respiratory conditions other than chronic obstructive respiratory disease or asthma, including: emphysema, chronic bronchitis, pulmonary fibrosis, fibrosing alveolitis, cystic fibrosis etc.	277, 490, 515, 516	J40, J84, E84	
Asthma	493	J45, J46	
Cerebrovascular disease	362.3, 430, 431, 433.x1, 434, 435, 436	G45.0, G45.1, G45.2, G45.3, G45.8, G45.9, H34.1, I60, I61, I63, I64	Exclude if any traumatic brain injury code (ICD-9: 800-804, 850-854; ICD-10-CA: S02.0-S02.4, S02.6, S02.8, S02.9, S06) is used or the rehabilitation care code (ICD-9: V57; ICD-10-CA: Z50) is the primary hospital discharge diagnosis
Ischemic heart disease	410, 413, 414	I20, I21, I25	
Chronic Neurodegenerative Diseases (Multiple Sclerosis, Amyotrophic Lateral Sclerosis, Parkinson's disease, Alzheimer's disease, stroke or other brain injury with a permanent neurological deficit, paraplegia or quadriplegia etc.)	290, 330-337, 340-344, 800-804, 850-854	F00-F03, G11, G12, G20-G26, G30-G32, G35, G80-G83, S02.0- S02.4, S02.6, S02.8, S02.9, S06	
Chronic liver disease (hepatic failure)	571, 573	K70, K71, K72	

Note: ICD-9 indicates International Classification of Diseases 9th edition; ICD-10, International Classification of Diseases 10th edition, Canadian version.

Appendix C

Johns Hopkins Aggregated Diagnostic Groups (ADGs) and Adjusted Clinical Groups (ACGs) categories used

Aggregated Diagnostic Groups (ADGs)	
1	Time Limited: Minor
2	Time Limited: Minor -Primary Infections
3	Time Limited: Major
4	Time Limited: Major-Primary Infections
5	Allergies
6	Asthma
7	Likely to Recur: Discrete
8	Likely to Recur: Discrete-Infections
9	Likely to Recur: Progressive
10	Chronic Medical: Stable
11	Chronic Medical: Unstable
12	Chronic Specialty: Stable-Orthopedic
13	Chronic Specialty: Stable-Ear, Nose, Throat
14	Chronic Specialty: Stable-Eye
15	No Longer in Use
16	Chronic Specialty: Unstable-Orthopedic
17	Chronic Specialty: Unstable-Ear, Nose, Throat
18	Chronic Specialty: Unstable-Eye
19	No Longer in Use
20	Dermatologic
21	Injuries/Adverse Effects: Minor
22	Injuries/Adverse Effects: Major
23	Psychosocial: Time Limited, Minor
24	Psychosocial: Recurrent or Persistent: Stable
25	Psychosocial: Recurrent or Persistent: Unstable
26	Signs/Symptoms: Minor
27	Signs/Symptoms: Uncertain
28	Signs/Symptoms: Major
29	Discretionary
30	See and Reassure
31	Prevention/Administrative
32	Malignancy
33	Pregnancy
34	Dental

Adjusted Clinical Groups (ACGs)	
0100	Acute minor, age 1
0200	Acute minor, age 2-5
0300	Acute minor, age 6+
0400	Acute major
0500	Likely to recur, without allergies
0600	Likely to recur, with allergies
0700	Asthma
0800	Chronic medical, unstable
0900	Chronic medical, stable
1000	Chronic specialty, stable
1100	Eye/dental
1200	Chronic specialty, unstable
1300	Psychosocial, without psychosocial unstable
1400	Psychosocial, with psychosocial unstable, without psychosocial stable
1500	Psychosocial, with psychosocial unstable and psychosocial stable
1600	Preventive/administrative
1711	Pregnancy: 0-1 ADGs, delivered
1712	Pregnancy: 0-1 ADGs, not delivered
1721	Pregnancy: 2-3 ADGs, no major ADGs, delivered
1722	Pregnancy: 2-3 ADGs, no major ADGs, not delivered
1731	Pregnancy: 2-3 ADGs, 1+ major ADGs, delivered
1732	Pregnancy: 2-3 ADGs, 1+ major ADGs, not delivered
1741	Pregnancy: 4-5 ADGs, no major ADGs, delivered
1742	Pregnancy: 4-5 ADGs, no major ADGs, not delivered
1751	Pregnancy: 4-5 ADGs, 1+ major ADGs, delivered
1752	Pregnancy: 4-5 ADGs, 1+ major ADGs, not delivered
1761	Pregnancy: 6+ ADGs, no major ADGs, delivered
1762	Pregnancy: 6+ ADGs, no major ADGs, not delivered
1771	Pregnancy: 6+ ADGs, 1+ major ADGs, delivered
1772	Pregnancy: 6+ ADGs, 1+ major ADGs, not delivered
1800	Acute minor and acute major
1900	Acute minor and likely to recur, age 1
2000	Acute minor and likely to recur, age 2-5
2100	Acute minor and likely to recur, age>5, without allergy
2200	Acute minor and likely to recur, age>5, with allergy
2300	Acute minor and chronic medical: stable
2400	Acute minor and eye/dental

2500	Acute minor and psychosocial without psychosocial unstable
2600	Acute minor and psychosocial with psychosocial unstable without stable
2700	Acute minor and psychosocial with psychosocial unstable & stable
2800	Acute major and likely to recur
2900	Acute minor/acute major/likely to recur, age 1
3000	Acute minor/acute major/likely to recur, age 2-5
3100	Acute minor/acute major/likely to recur, age 6-11
3200	Acute minor/acute major/likely to recur, age >=12, without allergy
3300	Acute minor/acute major/likely to recur, age >=12, with allergy
3400	Acute minor/likely to recur/eye & dental
3500	Acute minor/likely to recur/psychosocial
3600	Acute Minor/Acute Major/Likely to Recur/Chronic Medical: Stable
3700	Acute Minor/Acute Major/Likely to Recur/Psychosocial
3800	2-3 Other ADG Combinations, Age 1-17
3900	2-3 Other ADG Combinations, Males Age 18-34
4000	2-3 Other ADG Combinations, Females Age 18-34
4100	2-3 Other ADG Combinations, Age > 34
4210	4-5 Other ADG Combinations, Age 1-17, no major ADGs
4220	4-5 Other ADG Combinations, Age 1-17, 1+ major ADGs
4310	4-5 Other ADG Combinations, Age 18-44, no major ADGs
4320	4-5 Other ADG Combinations, Age 18-44, 1 major ADG
4330	4-5 Other ADG Combinations, Age 18-44, 2+ major ADGs
4410	4-5 Other ADG Combinations, Age > 44, no major ADGs
4420	4-5 Other ADG Combinations, Age > 44, 1 major ADG
4430	4-5 Other ADG Combinations, Age > 44, 2+ major ADGs
4510	6-9 Other ADG Combinations, Age 1-5, no major ADGs
4520	6-9 Other ADG Combinations, Age 1-5, 1+ major ADGs
4610	6-9 Other ADG Combinations, Age 6-17, no major ADGs
4620	6-9 Other ADG Combinations, Age 6-17, 1+ major ADGs
4710	6-9 Other ADG Combinations, Males Age 18-34, no major ADGs
4720	6-9 Other ADG Combinations, Males Age 18-34, 1 major ADG
4730	6-9 Other ADG Combinations, Males Age 18-34, 2+ major ADGs
4810	6-9 Other ADG Combinations, Females Age 18-34, no major ADGs
4820	6-9 Other ADG Combinations, Females Age 18-34, 1 major ADG
4830	6-9 Other ADG Combinations, Females Age 18-34, 2+ major ADGs
4910	6-9 Other ADG Combinations, Age > 34, 0-1 major ADGs
4920	6-9 Other ADG Combinations, Age > 34, 2 major ADGs
4930	6-9 Other ADG Combinations, Age > 34, 3 major ADGs
4940	6-9 Other ADG Combinations, Age > 34, 4+ major ADGs
5010	10+ Other ADG Combinations, Age 1-17, no major ADGs
5020	10+ Other ADG Combinations, Age 1-17, 1 major ADG
5030	10+ Other ADG Combinations, Age 1-17, 2+ major ADGs
5040	10+ Other ADG Combinations, Age 18+, 0-1 major ADGs
5050	10+ Other ADG Combinations, Age 18+, 2 major ADGs
5060	10+ Other ADG Combinations, Age 18+, 3 major ADGs
5070	10+ Other ADG Combinations, Age 18+, 4+ major ADGs
5110	No Diagnosis or Only Unclassified Diagnosis
5200	Non-Users
5311	Infants: 0-5 ADGs, no major ADGs, low birthweight
5312	Infants: 0-5 ADGs, no major ADGs, normal birth-weight
5321	Infants: 0-5 ADGs, 1+ major ADGs, low birthweight
5322	Infants: 0-5 ADGs, 1+ major ADGs, normal birth-weight
5331	Infants: 6+ ADGs, no major ADGs, low birthweight
5332	Infants: 6+ ADGs, no major ADGs, normal birthweight
5341	Infants: 6+ ADGs, 1+ major ADGs, low birthweight
5342	Infants: 6+ ADGs, 1+ major ADGs, normal birthweight
9900	Invalid Age

Appendix D

The distribution of 11 chronic conditions reflected in the chronic disease registry (CDR) but not in 2012/13 data

Condition	Frequency	Percentage
Hypertension	497,324	21.92%
Asthma	276,577	12.19%
Ischemic heart disease	274,577	12.10%
Chronic respiratory disease	258,589	11.40%
Chronic neurodegenerative disease	216,522	9.54%
Diabetes	199,018	8.77%
COPD	140,972	6.21%
Chronic kidney disease	111,518	4.92%
Cerebrovascular disease	109,425	4.82%
Chronic liver disease	100,869	4.45%
Congestive heart failure	83,491	3.68%

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UBC Centre for Health Services and Policy Research
The University of British Columbia
201-2206 East Mall
Vancouver, B.C. Canada V6T 1Z3
Email: chspr.reception@ubc.ca

www.chspr.ubc.ca