BMJ Open

Longitudinal trajectories of health care costs among high-need high-cost patients in British Columbia, Canada

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2024-089693
Article Type:	Original research
Date Submitted by the Author:	07-Jun-2024
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Keywords:	Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Health economics < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Health Care Costs

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Title: Longitudinal trajectories of health care costs among high-need high-cost patients in British Columbia, Canada

Running Title: Health care cost trajectories

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Keywords: patient-oriented research; health care costs; high-cost users; administrative data; longitudinal studies (MeSH); latent class analysis (MeSH)
Words: 3,388
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Ethical approval: This study was approved by the University of British Columbia Research Ethics Board (H20-00029).
Data availability statement: This analysis was conducted using administrative data from Population Data BC. Access to data provided by the Data Steward(s) is subject to approval, but can be requested for research projects through the Data Steward(s) or their designated service providers. All inferences, opinions, and conclusions drawn in this publication are those of the author(s), and do not reflect the opinions or policies of the Data Steward(s).
Funding: This study was supported by funding from the EuroQol Foundation (164-2020RA) and the BC SUPPORT Unit Health Economics and Simulation Modelling Methods Cluster. Logan Trenaman was supported by a Canadian Institutes of Health Research Postdoctoral Fellowship in Patient-Oriented Research. Mark Harrison received salary support through a 2017 Scholar Award from the Michael Smith Foundation for Health Services Research and a 2016 Young Investigator Salary Award from The Arthritis Society (YIS-16-104). The funders had no role in the study design; the collection, analysis, and interpretation of data; the writing of the manuscript; or the decision to submit the article for publication.
Contributors: LT designed the research and analysis plan in consultation with and using feedback from all the authors. DG and LT conducted the analysis. LT wrote the first draft of the manuscript. All authors contributed to the interpretation of the results and critical revision of the manuscript for important intellectual content and approved the final version. LT is the guarantor of the work and affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as originally planned (and, if relevant, registered) have been explained. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

ABSTRACT

Objectives: We sought to identify groups of high-need high-cost (HNHC) patients with distinct cost trajectories and describe the sociodemographic and clinical characteristics associated with group membership.

Design: A population-based retrospective cohort study, using administrative health data.

Setting: British Columbia, Canada.

Participants: People who were high-need high-cost (HNHC) in 2017, defined as incurring health system costs in the top 5% of the population, and were continuously registered in the Medical Service Plan from January 2015 to December 2019 and alive at the end of the study period.

Outcome measures: The primary objective was to identify longitudinal patterns of health care costs using group-based trajectory modeling. Adopting a health sector perspective, we conducted person-level costing for hospital episodes, day surgeries, physician services, prescription medications, and home and community care services. The secondary objective was to explore sociodemographic and clinical characteristics associated with group membership using adjusted odd-ratios and 95% confidence intervals from a multinomial logistic regression model.

Results: Our final sample comprised 5.4 million British Columbians. In 2017, 161,323 people met our definition of a HNHC and were included in our analysis (threshold: $10,448). We selected a model with five groups. These groups included those with persistently very high-costs (44%, mean five-year total: $124,622); persistent high-costs (32%, mean five-year total: $ 38,997); rising costs (7%, mean five-year total: $43,140); declining costs (10%, mean five-year total: $30,545); and those with a cost spike (7%, mean five-year total: $19,601). Being older, being in the lowest income quintile, and the presence of nearly every comorbidity in the Elixhauser index were associated with increased odds of being in the persistently very-high-cost trajectory group relative to each other group.

Conclusion: This study unveils the complex and diverse cost trajectories of HNHC patients in BC, highlighting the necessity for tailored healthcare strategies that address individual patient needs and circumstances. Notably, a high proportion of HNHC patients exhibit persistently high-costs over a five-year period, and available sociodemographic and clinical data do a poor job of predicting group membership. Future research is needed to develop methods for predicting future HNHC patients before, and to identify evidence-based interventions that can improve patient outcomes and mitigate unnecessary health care utilization and costs.

What is already known on this topic?
- A relatively small proportion of the population incurs a disproportion amount of health care expenditures. This group is known as high-need high-cost (HNHC) patients. - The long-term cost trajectories of HNHC patients are not well understood, and characterizing these trajectories and factors associated with them to support targeted intervention to improve outcomes and reduce costs.
What this study adds
- HNHC patients in British Columbia Canada exhibit heterogenous long-term cost trajectories, including persistently very-high or high-cost, rising costs, declining costs, and a cost spike. - Multimorbidity is a hallmark of those associated with the persistently high-cost trajectory, however available clinical and socio-demographic data does a poor job of predicting trajectory group membership. - This study highlights the complex nature of HNHC patients' health care utilization, and highlights the need for tailored, evidence-based interventions to address the unique clinical needs of this population.

1 INTRODUCTION

Health care expenditures are highly concentrated in a relatively small proportion of the population.[1–4] A systematic review of 55 studies found that over half of all health care costs were incurred by just 5% of the population, while nearly a quarter were incurred by 1% of the population.[3] This relatively small segment of the population that incurs a disproportionate amount of health care costs are known as high-need high-cost (HNHC) patients. A substantial amount of research has focused on describing the characteristics of HNHC patients and their health care use.[3] HNHC patients often have multiple chronic conditions and functional limitations, and their risk of being HNHC may be amplified by the presence of other co-occurring health conditions, such as mental illness and substance misuse, and social risk factors, such as homelessness, low socioeconomic status, and food insecurity.[5–9] The relationship between demographic characteristics and HNHC status is less clear,[5] however increasing age and being near the end of life have are associated with an increased risk of being a HNHC patient.[3]

While HNHC patients are united in their high health care use, they are a heterogeneous population.[10] Consequently, research has focused on segmenting the population into groups who have similar demographic and clinical profiles.[11–13] For example, Wick *et al.* used latent class analysis to describe groups of persistently high-cost patients, defined as those who were HNHC for two consecutive years. Nine groups were identified, including those characterized by severe mental illness or cardiovascular disease, each of which would need different interventions or supports to improve their care and outcomes.[13]

Given the clinical heterogeneity in HNHC patients, we might expect this to translate into heterogeneity in their costs over time. While selected studies have described the health care use and costs among HNHC patients,[10,14,15] the long-term cost trajectories of HNHC patients have not been well characterized.[16–19] Importantly, understanding the path to (or from) HNHC status and the factors associated with different trajectories may identify opportunities to intervene to improve patient outcomes and reduce costs.[15] In this study we had two aims, to: 1) identify groups of high-need high-cost patients with distinct cost trajectories, and 2) describe the sociodemographic and clinical characteristics associated with group membership.

2 METHODS

This study was approved by the UBC Behavioural Ethics Research Board (H20-00029). Reporting followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines and the Guidelines for Reporting on Latent Trajectory Studies (GRoLTS) checklist.[20,21]

2.1 Study design and setting

Our study used five calendar years of data from Population Data BC.[22] This included data from the Discharge Abstract Database (hospital separations, including day surgeries), National Ambulatory Care Reporting

System (emergency department), Medical Services Plan (MSP: fee-for-service physician services), PharmaNet database (prescription medications and medical supplies), and Home and Community Care database (long-term care, assisted living, adult daycare, and home care). Our final sample included all British Columbians who were continuously registered in the MSP from January 2015 to December 2019 and alive at the end of the study period.

2.2 Costing

We conducted person-level costing with a health system perspective, following best practice guidelines from Canada. For example, inpatient hospitalizations were costed from the Discharge Abstract Database using case-mix costing which involves multiplying the cost of a standard hospital stay by a resource intensity weight.[23] Emergency department care was costed by identifying unique visits using the National Ambulatory Care Reporting System database, Discharge Abstract Database, and Medical Service Plan database, and multiplying each by a ED facility cost for each encounter.[24] Home and community care costs were estimated using the Home and Community Care database, which includes multiplying the number of days in care by an estimated cost per day, which is calculated by dividing residential care expenditures by the total number of residential care days. Lastly, physician and prescription drug costs were obtained directly from the Medical Service Plan and PharmaNet databases, respectively.

We began by aggregating costs at the daily level, with costs spanning multiple days (e.g., hospitalization, 30-day prescription) distributed evenly across the period. Costs were then aggregated at the monthly level. This approach has been used previously, and helps to assess trends over time.[16] Costs were adjusted to 2019 Canadian dollars using the health and personal care component of the Consumer Price Index. We defined HNHC patients as those incurring annual health care costs in the top 5% of the population. In each calendar year of the study period every individual in our sample was classified as either HNHC, or not.

2.3 Statistical analysis

We conducted a descriptive analysis of healthcare costs in our sample over the study period. The standard three-step method identified groups and explored the predictors of class membership.[21] The first step identified the number of unique cost trajectory groups using group-based trajectory modeling (GBTM). The second step identified the most likely cost trajectory group for everyone, and the third step used a multinomial logistic regression model to investigate covariates associated with membership in each group.

2.3.1 Descriptive analysis

Descriptive analysis focused on describing overall cost characteristics by percentile definitions for HNHC patients, including those incurring costs in the top 1%, 5%, and 10% of the population. We summarized

costs (total and by cost category) using descriptive statistics (mean; standard deviation; median; interquartile range)

2.3.2 Identification of cost trajectory groups

Trajectory modeling is widely used in clinical research to understand the change in an outcome over time.[25] Nagin and Odgers identify three different types of trajectory models, including 1) Growth Curve Modeling (GCM), Growth Mixture Modeling (GMM), and Group-Based Trajectory Modeling (GBTM).[25] We chose not to use GCM because it requires an assumption that all individuals in the population follow a similar trajectory,[25] which prior research demonstrates is not a reasonable assumption in the current context.[17] Both GMM and GBTM allow for groups of the population of interest to follow different trajectories,[26] however they differ in that GBTM assumes all individuals within a group follow the same trajectory whereas GMM includes random effects, which is more computationally intensive, but also captures differences in trajectories amongst individuals in the same trajectory group.[26] We chose GBTM over GMM because our focus was on identifying groups of individuals who share similar cost trajectories and could be targeted with tailored policies or interventions. This does not require understanding heterogeneity amongst the different trajectory groups.

Here, we implemented GBTM to identify groups with distinct trajectories of quarterly log-costs (*PROC TRAJ* function in SAS). Our analysis of cost trajectories focused on those who were a HNHC patient in 2017, i.e. the middle year of the study period. The focus on HNHC patients from a single calendar year simplified the analysis. Including participants designated as a HNHC patient in any calendar year would result in users with similar cost trajectories (e.g., a cost spike) that occur in different years being modeled together. This could dilute trends or result in an inflated number of trajectory groups which reflect differential timing rather than unique trajectories. We began by fitting models that include 2 to 10 trajectory groups with up to 4th-order polynomials. We did not consider covariates in the model.[21] We chose our final model and identified the number of trajectory groups using several criteria, including Akaike and Bayesian information criteria (AIC and BIC), log-likelihood, and entropy, visual assessment of the trajectory groups to ensure that they were distinct from each other, and evaluating the posterior probability of group membership to ensure it exceeded a minimal threshold of >0.7.[25] We conducted sensitivity analyses to explore the impact of modeling decisions on our results. This included exploring the impact of different samples (e.g., HNHC in 2016; 2018), threshold definitions of HNHC patients (top 1%; top 10%), and ways of modeling cost (monthly costs; rolling costs). We assumed that resource use and cost data were comprehensive, thus, there were no missing data for our GBTM analysis.

2.3.3 Characteristics associated with trajectory group membership

We explored the association between time stable sociodemographic and clinical covariates and group membership using a multinomial logit model.[25] The model included age, sex, urban area (rural versus metropolitan), neighborhood income quintile, and comorbid conditions as measured using the Elixhauser Comorbidity Index.[27] Age, sex, urban area, and neighborhood income quintiles were measured using data from the first year of our analysis (2015). All 30 comorbidities in the index were measured across the five-year study period (2015-2019) and dichotomized as either present or absent. We also included a variable which counted the total number of comorbidities and categorized individuals as having either 0, 1, 2, 3, and 4 or more comorbid conditions. Model selection was conducted using stepwise backward variable selection, and we chose the best model based on the AIC. As a sensitivity analysis we also conducted variable selection using stepwise forward variable selection. We assumed that our data on comorbidities were comprehensive (i.e., no missingness) however there were missing demographic data. Given the small relatively small proportion of missingness, we conducted a complete case analysis to identify the characteristics associated with trajectory group membership.

2.4 Patient and Public Involvement

Two patient partners (MP; KW) were members of the research team. There contributions included outlining the research questions, participating in all team meetings, providing feedback on the analysis plan, and reviewing and providing critical feedback on the manuscript and other dissemination materials including conference abstracts and presentations. Their feedback was critical in the decision to use the GBTM methodology. They felt it was important to explore the longitudinal cost trajectories of people who transition to or from HNHC status, and that the graphical output provided by GBTM was a more intuitive way to engage with the results.

3 RESULTS

Our final sample comprised 5.4 million persons. The cumulative distribution of health care expenditures by the percent of the population is presented in Figure 1. We found that in 2017 approximately 27% of British Columbians incurred no health care costs, while the top 10%, 5%, and 1% accounted for 79%, 67%, and 36% of health care expenditures, respectively. Over 224,000 British Columbians met our definition of being a HNHC patient in 2017 (cost threshold to be in the top 5% was $7,968). Of these individuals, 39% were HNHC in one-year (2017), while 21%, 15%, 10%, 15% were HNHC for two-, three-, four-, and five-years, respectively. Compared to the British Columbia (BC) population, HNHC patients tended to be older, were more likely to be female, and to have a higher number of comorbid conditions (see Table 1).

3.1 Identification of cost trajectory groups

GBTM results for four to seven trajectory groups are presented in the Appendix (Figure A1), while model fit statistics are available in Table A1. We selected a five-group model of cost trajectories (Figure 2). The figure includes the mean actual (solid line) and predicted trajectories (dashed line) for each group. The groups included 1) persistent very-high-cost (44.0%), 2) persistent high-cost (31.8%), 3) rising cost (10.3%), 4) declining cost (7.1%) and 5) those exhibiting a cost spike (6.8%). All told, over three quarters of HNHC patients were associated with a persistent very-high-cost or high-cost trajectory group. The mean trajectories for each group alongside individual trajectories (1% sample) are presented in Appendix Figure A2 while the model parameters are described in Table A2. Sensitivity analyses found similar trajectory groups in HNHC patients from the prior or following year (Figure A3) and for different HNHC thresholds (Figure A4).

Table 2 describes the cumulative cost profile of each of the five trajectory groups over the five-year study period. On average, those in the persistent very-high-cost trajectory group incurred the highest costs (mean: $124,622, SD = $92,700; median: $85,735, IQR = $52,305 to $148,838). In contrast, those in the cost-spike trajectory group incurred the lowest costs, (mean: $19,601, SD = $5,181; median: $13,828, IQR = $10,976 to $20,112).

3.2 Characteristics associated with trajectory group membership

The distribution of observable patient characteristics by trajectory group is available in Appendix Table A3. The results of the multinomial logit model estimated using stepwise backward variable selection (adjusted odds ratios and 95% confidence intervals) are presented in Figure 3 and Appendix Table A4. Of all the variables considered, all but one comorbidity indicator from the Elixhauser index (peripheral vascular disorders) was retained in the final model following stepwise backward variable selection. Membership in the persistently very-high-cost trajectory group was associated with increased odds of being older, living in a metropolitan (rather than non-metropolitan) area, and a neighborhood with lower average household income. With respect to comorbid conditions, those associated with a persistently very-high-cost trajectory group had increased odds of reporting a greater number of comorbid conditions. There were increased odds of most comorbid conditions in the persistently very-high-cost group relative to the other groups, including the persistent high-cost trajectory group. Some notable results include that the persistently high-cost trajectory group was associated with decreased odds of common ambulatory care sensitive conditions, including congestive heart failure, chronic pulmonary disease, and diabetes. In contrast, being in the persistent very-high-cost trajectory group was associated with decreased odds of hypertension, alcohol abuse, and metastatic and non-metastatic cancers, relative to the other four trajectories. The overall fit of the model as measured by McFadden's pseudo-R^2, which represents the proportion of variance in the dependent variable that is explained by the independent variables, was 0.1 (Nagerkerke R^2=0.16). Our

sensitivity analysis using stepwise forward variable selection using AIC resulted in the same model specification as stepwise backward variable selection. Results from the stepwise forward variable selection process are presented as a forest plot in Appendix Figure A5.

4 DISCUSSION

The study described the health care cost trajectories of HNHC patients in BC, Canada, over a five-year period. We found that HNHC patients exhibit heterogeneous longitudinal cost trajectories, however three quarters of HNHC patients were associated with either a persistent high-cost or persistent very-high-cost trajectory. We found that being in the persistent very-high-cost trajectory was associated with several factors, including older age, lower socioeconomic status, and multimorbidity.

There have been few applications of GBTM to model health care costs, often near the end of life and/or in specific clinical populations.[16,18,28–32] For example, Teraoka *et al.* used GBTM to explore health care costs for older adults in Japan in the final five-years of life.[30] They found that nearly three quarters of their sample was associated with the two most common trajectories, including persistent-high costs (46%) and persistent medium-to-high costs (26%). We had similar findings despite excluding those who died during the study period. Placona *et al.* explored latent cost trajectories of HNHC Medicare patients.[17] Despite using a different clustering method (k-means), definition of HNHC (top 10%), and length of analysis (three years), there were similarities to our findings. For example, Placona *et al.* identified three distinct cost trajectories in four and five group models (persistent high-cost; rising cost; and episodic high-cost) which closely mirror our own findings. They also found a high proportion of patients who were persistently high-cost across the study period (51%). Collectively, these results suggest that persistent high costs are a hallmark of the HNHC population. We found that over 60% of all HNHC patients in BC were under 65 years of age, and 39% had two or more comorbidities, as measured by the Elihxauser comorbidities index. In contrast, Guilcher *et al.* used Ontario administrative data from 2010/11 and found that a smaller proportion of the HNHC population was under 65 (48%) while nearly 59% had eight or more distinct comorbid conditions.[33] These discrepancies may reflect differences in the underlying population, time trends, or in the case of comorbidities, the specific indices used.

We conducted an analysis to determine which sociodemographic and clinical factors were associated with group membership. We found that being in the persistent very-high-cost group was associated with increased odds of being older and the presence of multiple comorbidities, both factors that have been identified previously.[3,5] We found that our overall model fit, as measured by McFadden's pseudo-R^2, was 0.1. Schneider *et al.* found a similar result despite focusing on a more clinically homogeneous population (people with advanced breast cancer at the end of life) and having access to patient hospital records which included detailed information on treatment.[16] Importantly, McFadden's pseudo-R^2 has been demonstrated

to be lower than other commonly used measures of R^2, with 0.2 to 0.4 "indicative of extremely good model fits" and "equivalenced to 0.7 to 0.9 for a linear function."[34] Regardless, the value obtained from our model falls outside this range, suggesting that there are other unknown variables, not included in this analysis, which may predict the cost trajectory groups. Previous research has highlighted the association between social factors and health behaviors and HNHC status.[7,8] However, we did not have comprehensive data on these factors. For example, we lacked an indicator for housing insecurity, relied on a proxy for socioeconomic status (neighborhood income quintile), and did not have information on self-reported health status, smoking status, or level of physical activity.

There are several clinical and policy implications of this work. Our results suggest that a considerable portion of HNHC patients incur persistently high health care costs, and these patients have high rates of multimorbidity. For example, nearly a quarter of patients associated with the persistent very-high-cost group had four or more comorbid conditions as measured by the Elixhauser index. There have been relatively few studies evaluating the impact of interventions targeting those with multimorbidity, with those that are available reporting either mixed results.[35] That said, we found evidence that several prevalent ambulatory care sensitive conditions (ACSC) associated with the persistent very-high-cost trajectory group, including chronic heart failure, COPD, and diabetes. Given that ACSCs are defined as conditions whereby timely and effective primary and outpatient care can reduce the risk of subsequent hospitalization,[36] identifying and targeting individuals who incur persistently high costs for ACSC is one potential area to improve outcomes and reduce costs. We also found that lower SES was associated with increased odds of being in the persistent very-high-cost trajectory. This is consistent with previous Canadian research that demonstrated that future high-cost health care use is strongly associated with SES, including income, housing, food security, and education.[7] This emphasizes that polices that target the social determinants of health, such as providing income support or access to affordable housing, have the potential to mitigate high health care utilization. Finally, our analysis has highlighted the limitations of administrative health data in capturing information on the social determinants of health, and the importance of improving the collection of these data so we can better understand their influence on health outcomes and health care use. This underscores the importance of efforts by groups like the World Health Organization, Healthy People 2030, and Canada Infoway, who are spearheading efforts to improve the routine collection of data on the social determinants of health.[37–39]

There are several strengths and limitations that warrant consideration. The strength of this study is that it uses health administrative databases, and as such, we have a large, representative sample of the BC population and comprehensive data on resource use and health system costs. Another strength is that we used five years of data which provides insight into how people transition to and from HNHC status. There are also some limitations. First, we excluded those who were not continuously enrolled in MSP, or those

that died during the five-year study period, meaning that our analysis may not be generalizable to these populations. Secondly, our costing approach did not capture some costs. For example, the PharmaNet database does not capture prescription drugs obtained in a hospital, or those administered through the BC Cancer Agency (i.e., oncology medications such as chemotherapy drugs), BC Transplant society (i.e., transplant-related drugs), or BC renal agency (i.e., drugs for kidney dialysis). Lastly, relying on administrative data alone means we could not explore the influence of social and behavioral factors on different cost trajectories. This could be accomplished by using linked survey data; however, this would dramatically reduce the sample size available for analysis.

4.1 Conclusions

HNHC patients in British Columbia exhibit heterogeneous longitudinal cost trajectories; however, a high proportion are associated with persistent costs over a five-year period. Multimorbidity is a hallmark of persistent very-high-costs, however, available socio-demographic and clinical data do a poor job explaining who is likely to be associated with different cost trajectories. Future work is needed to differentiate between preventable and non-preventable health care costs, develop methods for predicting people at-risk of becoming HNHC, and to identify interventions that can improve outcomes and reduce costs.

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Table 1. Characteristics of HNHC patients and the BC general population

	HNHC		BC	
	N=224,285		N=5,378,411	
	N	%	N	%
Age Group				
0-44	66,789	29.8%	3,211,043	59.7%
45-64	71,159	31.7%	1,459,001	27.1%
65-74	42,228	18.8%	442,627	8.2%
≥75	44,109	19.7%	265,659	4.9%
Missing	0	0.0%	81	0.0%
Sex				
Male	99,441	44.3%	2,670,537	49.7%
Female	124,837	55.7%	2,707,240	50.3%
Missing	7	0.0%	634	0.0%
Income Quintile				
1st	51,291	22.9%	896,900	16.7%
2nd	44,100	19.7%	903,394	16.8%
3rd	41,049	18.3%	908,806	16.9%
4th	39,893	17.8%	915,124	17.0%
5th	36,512	16.3%	873,204	16.2%
Missing	11,440	5.1%	880,983	16.4%
Geographic Region				
Metropolitan	117,296	52.3%	2,707,890	50.3%
Non-metropolitan (hub hospital)	80,899	36.1%	1,499,898	27.9%
Non-metropolitan (small/no hospital)	16,302	7.3%	325,156	6.0%
Remote	903	0.4%	16,590	0.3%
Missing	8,885	4.0%	828,877	15.4%
Comorbidities (Elixhauser)				
0	85,185	38.0%	4,815,139	89.5%
1	51,562	23.0%	312,107	5.8%
2	34,610	15.4%	129,128	2.4%
3	21,457	9.6%	59,972	1.1%
≥4	31,471	14.0%	62,065	1.2%

Figure 1. Distribution of health care expenditures in British Columbia in 2017

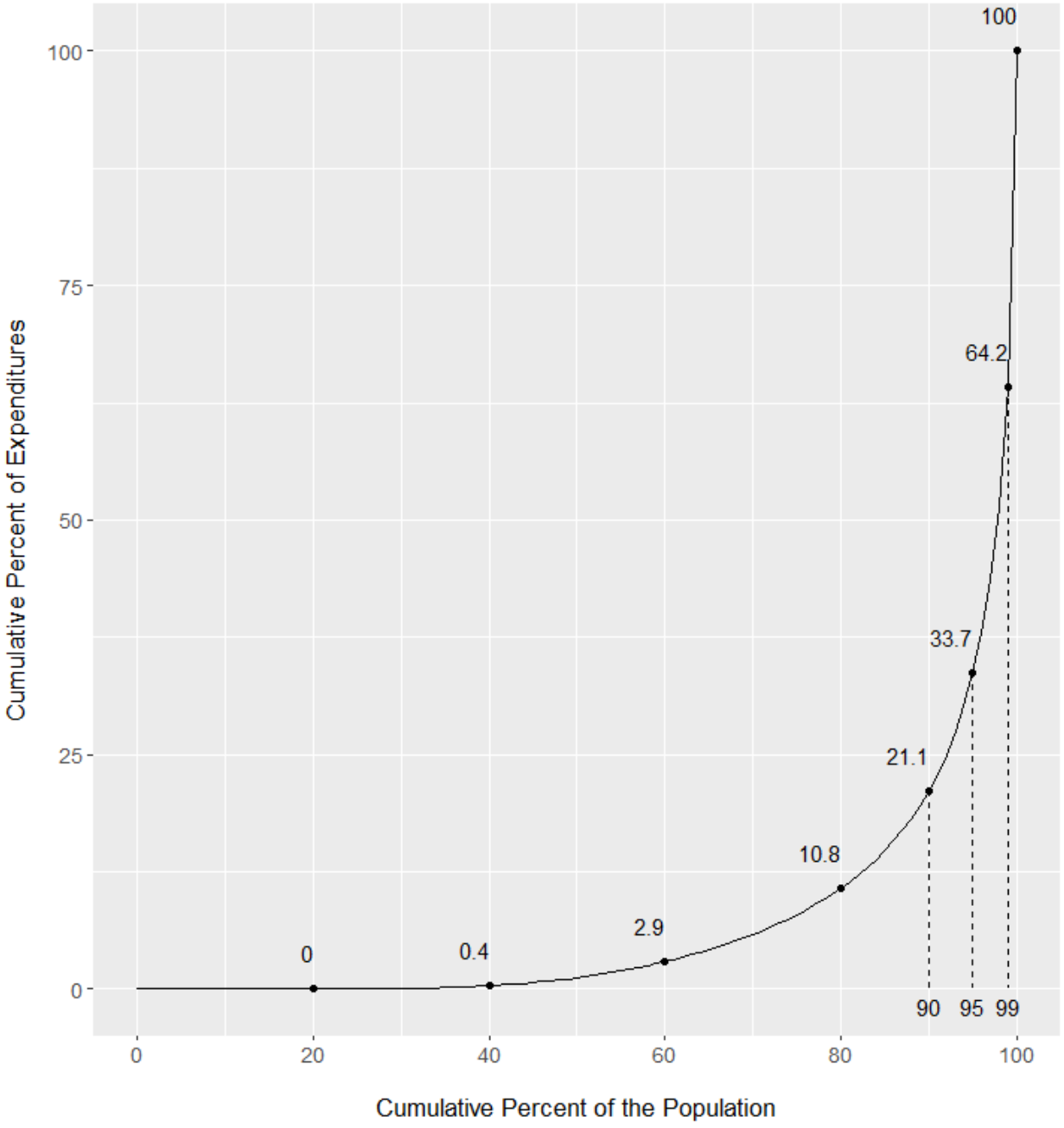


Figure 2. Actual (solid line) and predicted (dashed line) five-year cost trajectories from the five-group trajectory model of 2017 high-cost users in BC, Canada

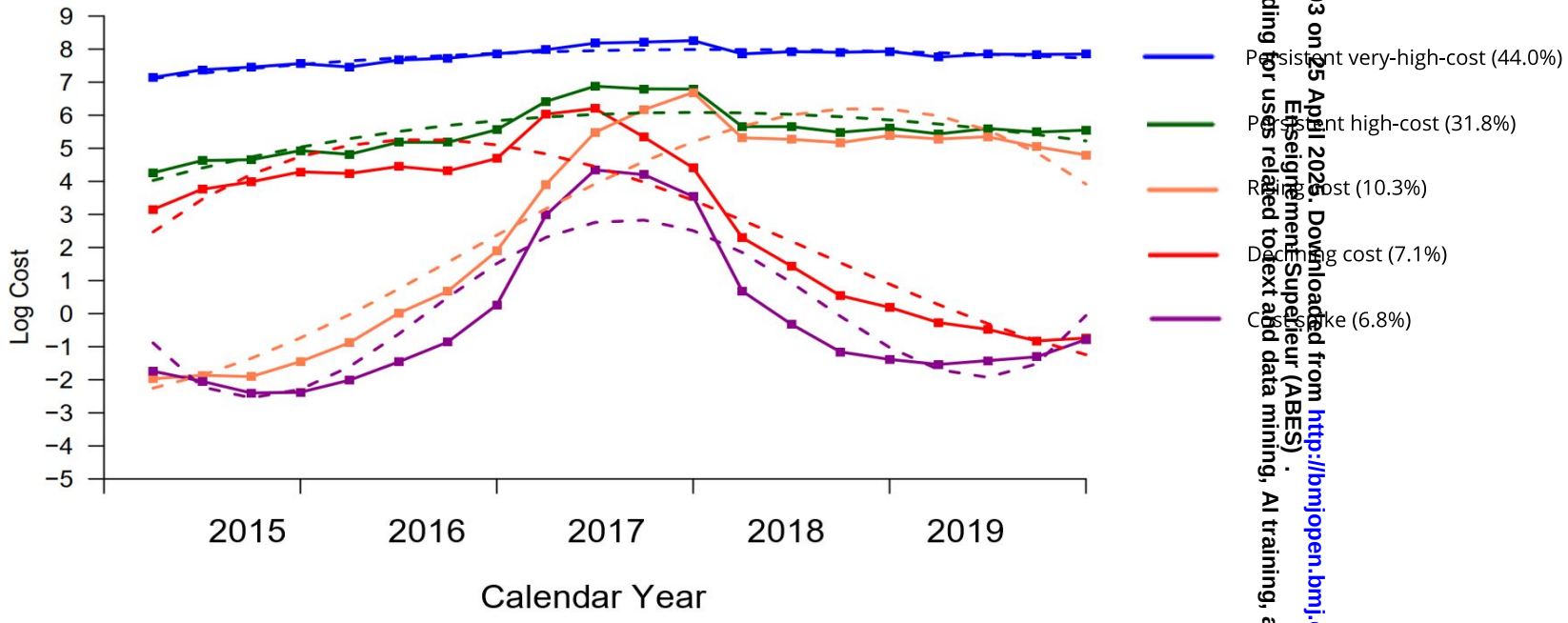
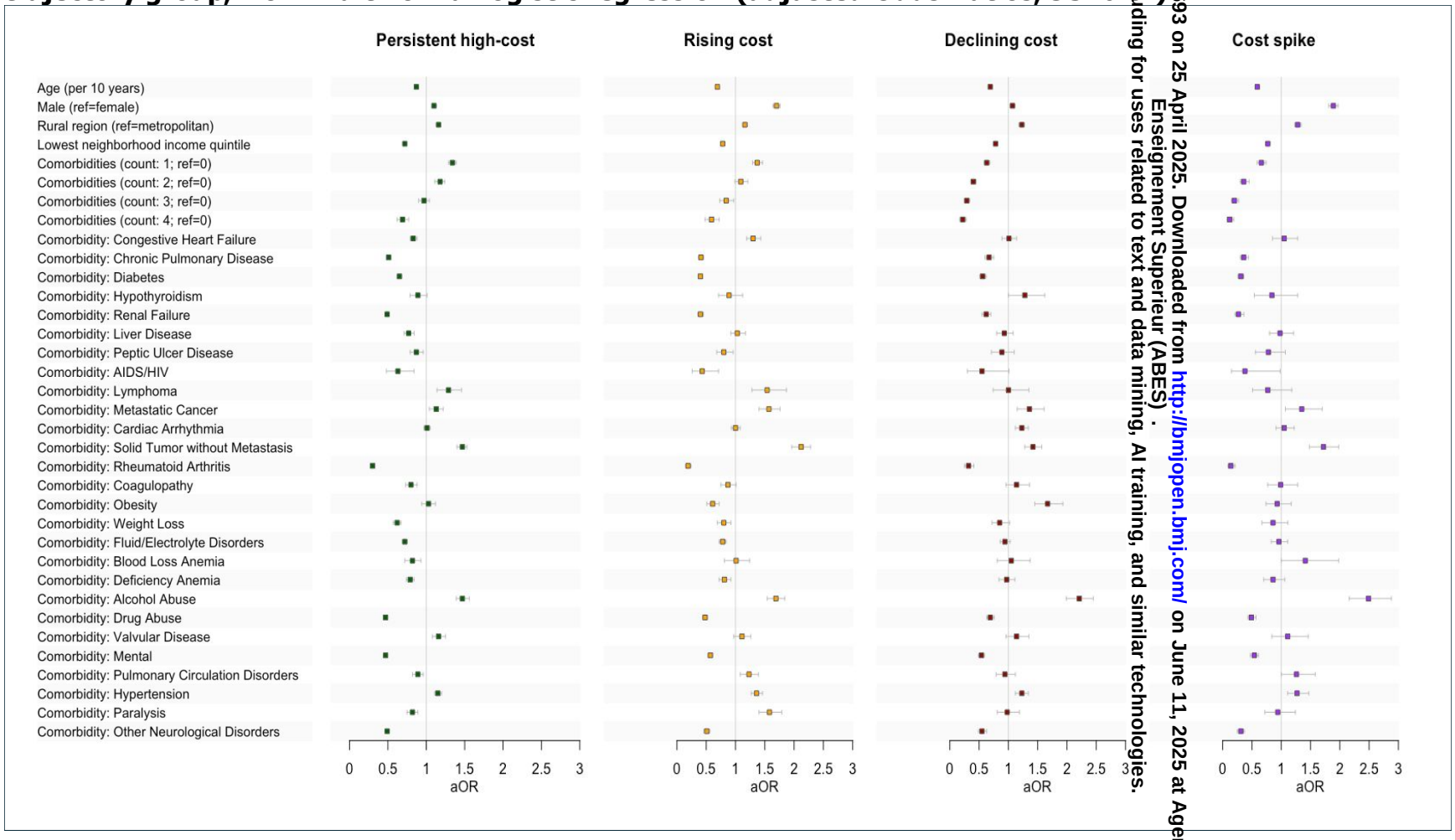


Table 2. Five-year costs by trajectory group, total and by cost category

		Persistent very-high-cost (44.0%)	Persistent high-cost (31.8%)	Rising cost (10.3%)	Declining cost (7.1%)	Cost spike (6.8%)
	N	99,122	71,095	22,998	15,99	15,177
Total Cost	Mean (SD)	$124,622 ($92,700)	$38,997 ($19,841)	$43,140 ($17,426)	$30,44 ($9,24	$19,601 ($5,181)
	Median (IQR)	$85,735 ($52,305, $148,838)	$28,259 ($20,097, $44,747)	$24,973 ($16,594, $47,846)	$19,62 ($14,288, $31,6	$13,828 ($10,976, $20,112)
Inpatient Care	Mean (SD)	$39,604 ($39,562)	$20,954 ($15,479)	$24,915 ($13,150)	$16,10 ($6,6	$12,715 ($4,533)
	Median (IQR)	$20,225 ($6,363, $48,792)	$12,987 ($8,022, $23,703)	$12,484 ($7,584, $25,840)	$9,22 ($6,233, $17,0	$8,441 ($5,898, $12,887)
Physician Services	Mean (SD)	$18,433 ($49,800)	$11,017 ($3,037)	$9,111 ($2,021)	$7,83 ($1,2	$4,755 ($741)
	Median (IQR)	$15,311 ($9,845, $22,428)	$10,014 ($7,487, $13,292)	$7,513 ($5,379, $10,851)	$6,36 ($4,886, $9,0	$4,320 ($2,970, $5,962)
Prescription Drugs	Mean (SD)	$25,570 ($27,293)	$3,461 ($6,650)	$4,004 ($4,408)	$3,881 ($3,4	$839 ($1,640)
	Median (IQR)	$9,904 ($2,091, $31,171)	$58 ($0, $1,487)	$0 ($0, $1,034)	$0 ($0, $2	$0 ($0, $0)
Emergency Department	Mean (SD)	$4,109 ($4,424)	$2,140 ($1,559)	$1,977 ($884)	$1,914 ($7	$1,129 ($362)
	Median (IQR)	$2,163 ($1,081, $4,686)	$1,442 ($721, $2,523)	$1,081 ($721, $2,523)	$1,081 ($360, $2,1	$721 ($360, $1,442)
Home and Community Care	Mean (SD)	$36,906 ($65,782)	$1,426 ($5,636)	$3,133 ($7,018)	$1,112 ($3,5	$163 ($397)
	Median (IQR)	$0 ($0, $15,266)	$0 ($0, $0)	$0 ($0, $0)	$0 ($0, $0)	$0 ($0, $0)

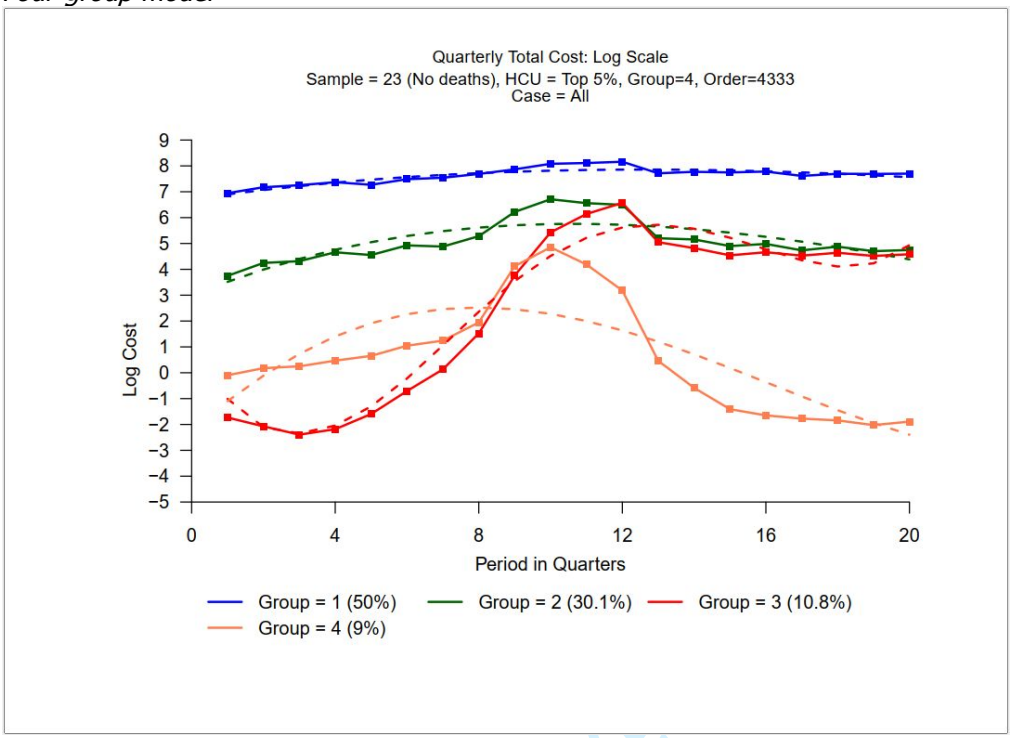
Figure 3. Forest plot of factors associated with group membership, relative to the 'very high-cost' trajectory group, from multinomial logistic regression (adjusted Odds Ratios, 95% CI)



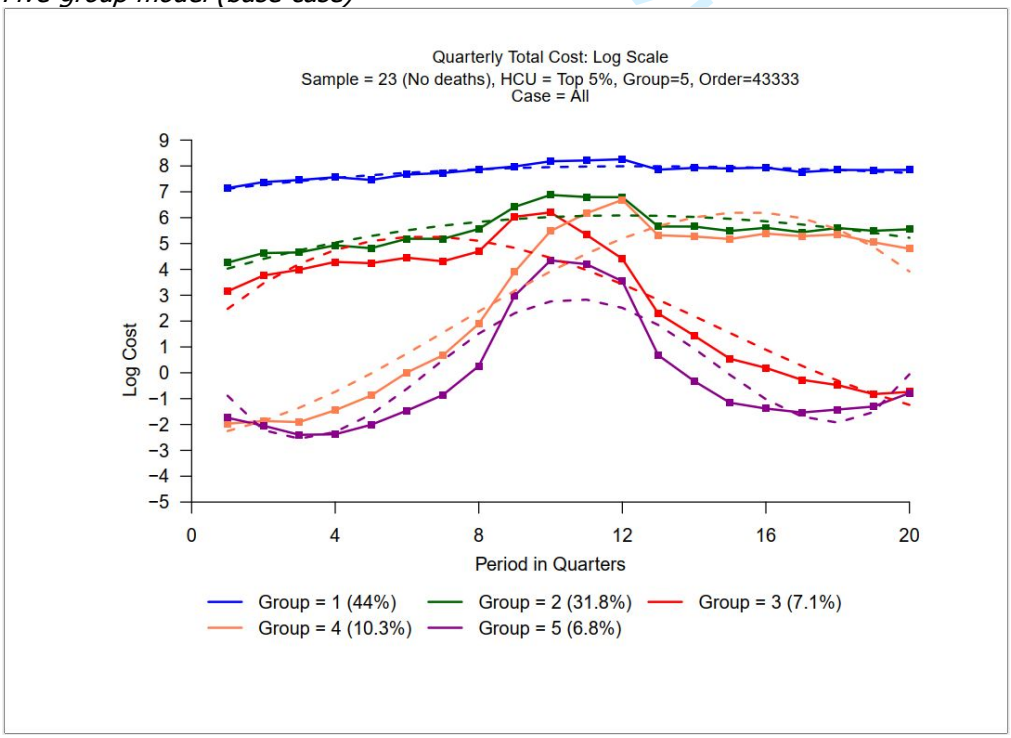
Appendix

Figure A1. Actual (solid line) and predicted (dashed line) five-year cost trajectories from group-based trajectory models with four to seven latent groups

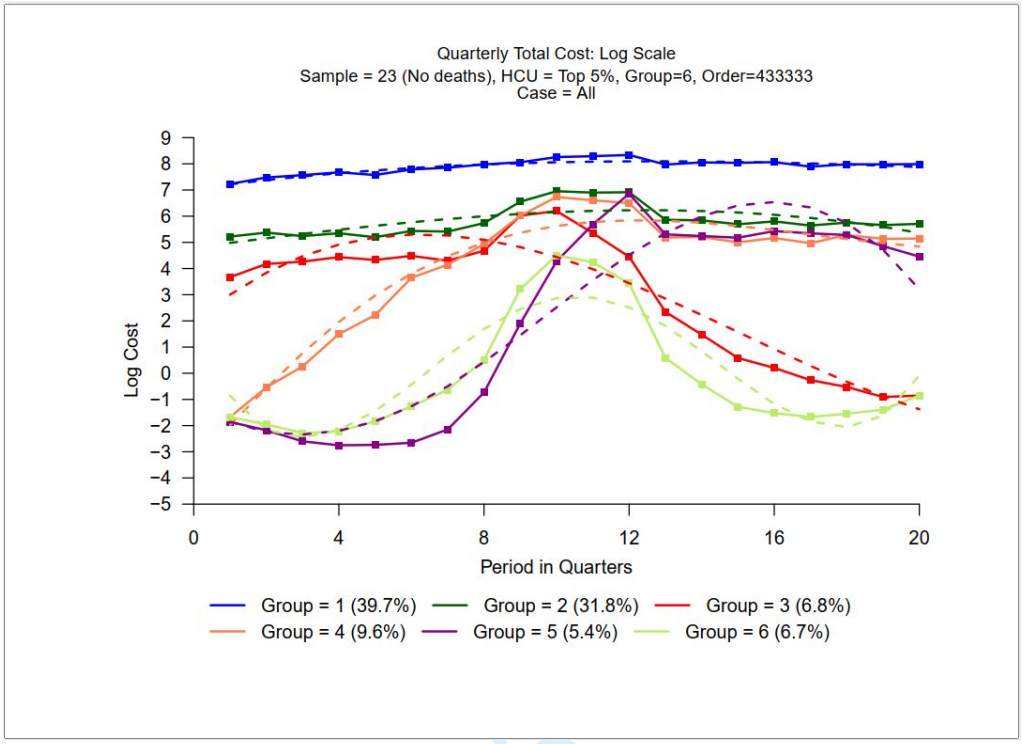
Four-group model



Five-group model (base-case)



Six-group model



Seven-group model

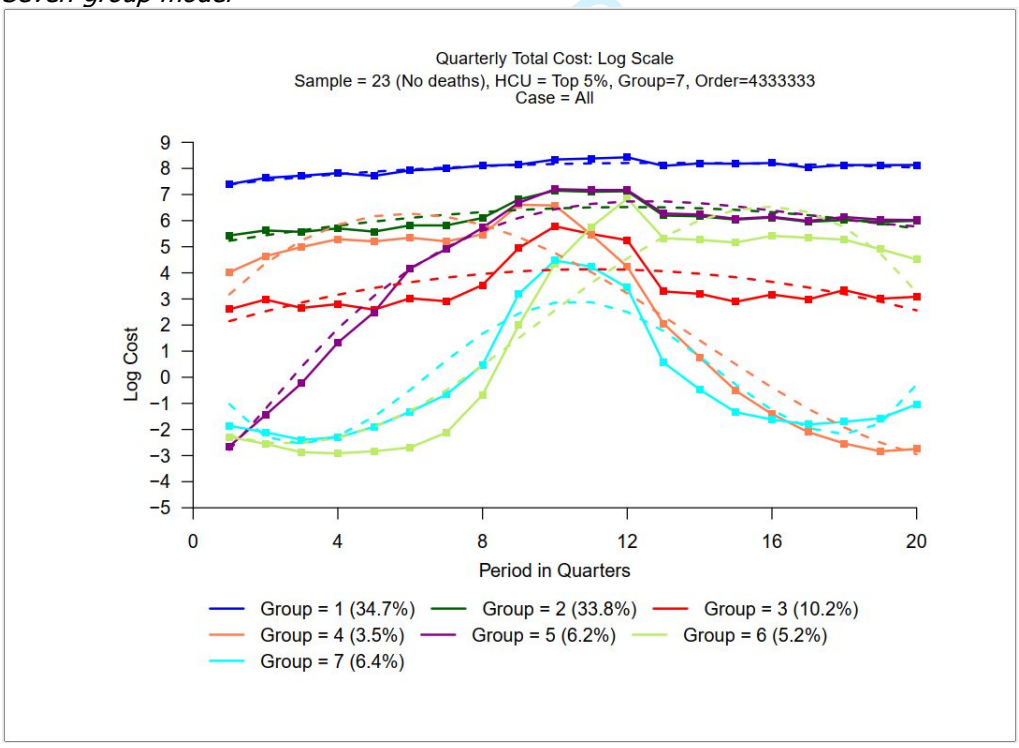


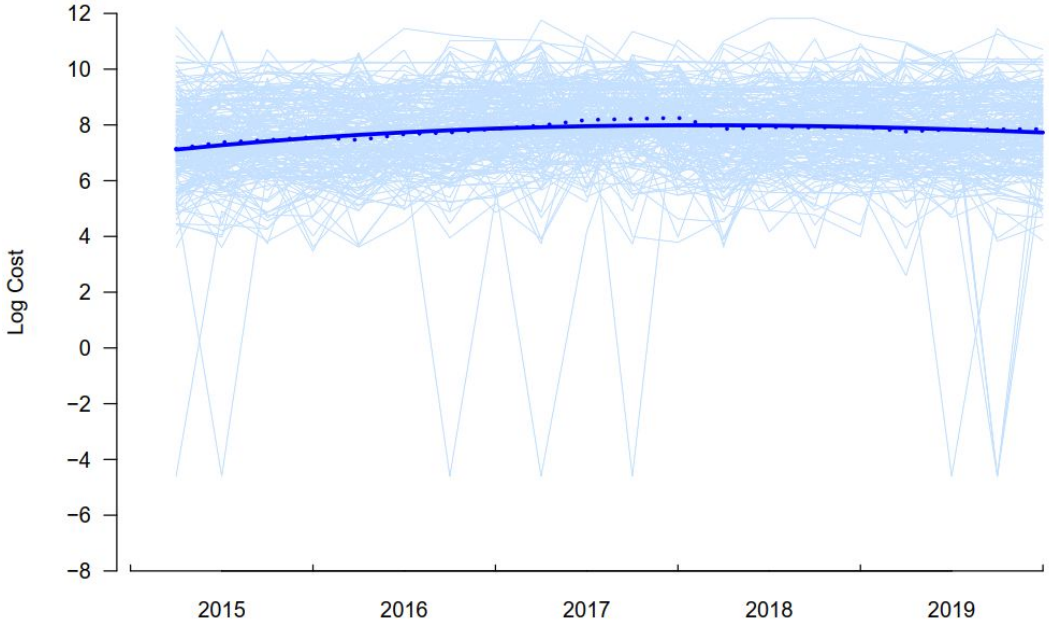
Table A1. Model fit statistics for group-based trajectory models with four to seven latent groups and 2nd to 4th degree polynomials*

groups	polynomials	BIC1	BIC2	AIC	LL	Change in BIC1	Change in BIC2	Entropy
4	4333	-11550175	-11550206	-11550066	-11550045			0.903
5	**43333**	**-11472689**	**-11472728**	**-11472555**	**-11472529**	**23891**	**23890**	**0.898**
6	433333	-11433127	-11433174	-11432967	-11432936	25155	25154	0.889
7	4333333	-11401437	-11401491	-11401252	-11401216	24975	24974	0.883

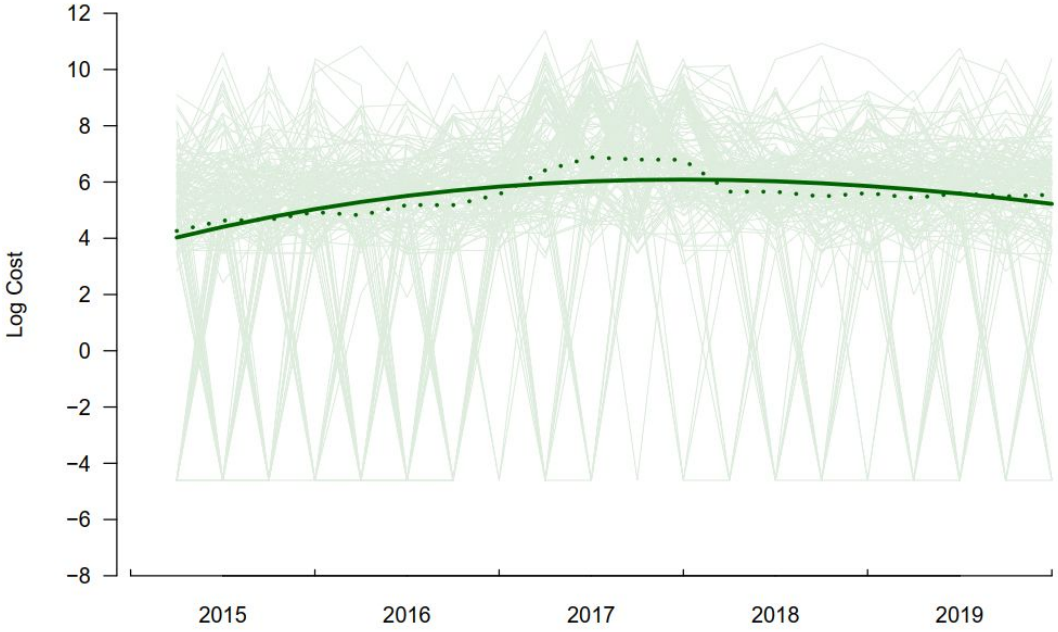
AIC: Akaike information criteria; BIC: Bayesian information criteria; LL: log-likelihood
* bolded model was selected as the base case

Figure A2. Mean trajectories for each latent group alongside individual trajectories (1% sample)

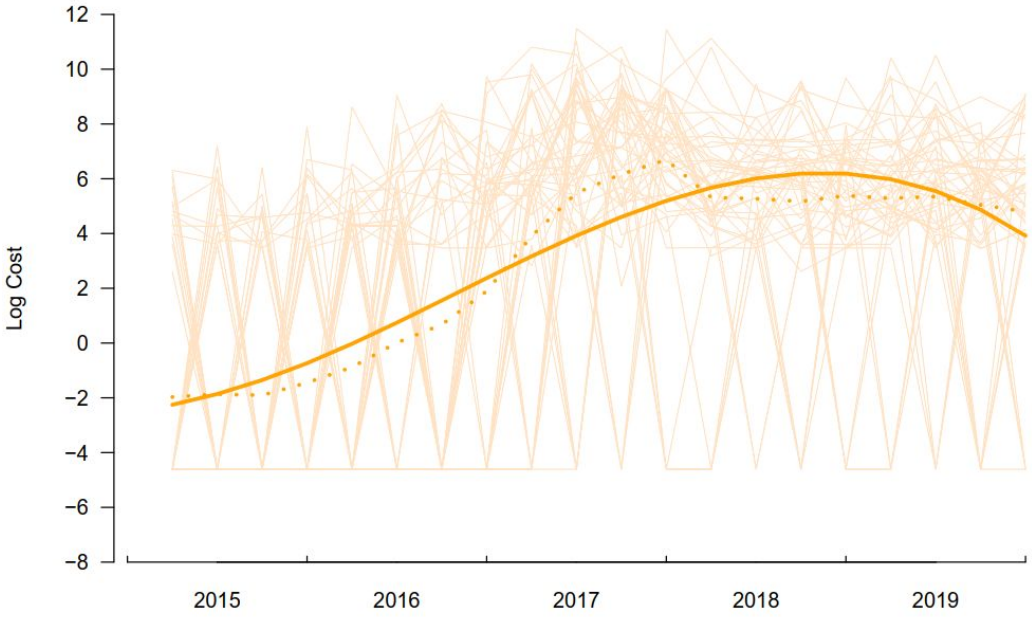
Group 1: Persistent very-high-cost



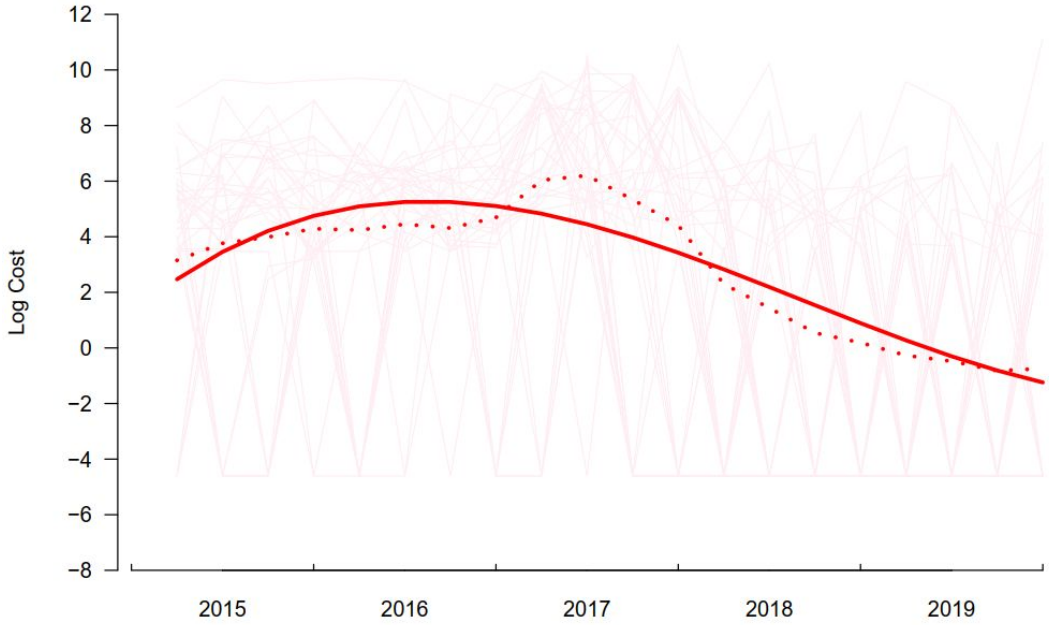
Group 2: Persistent high-cost



Group 3: Rising cost



Group 4: Declining cost



Group 5: Cost spike

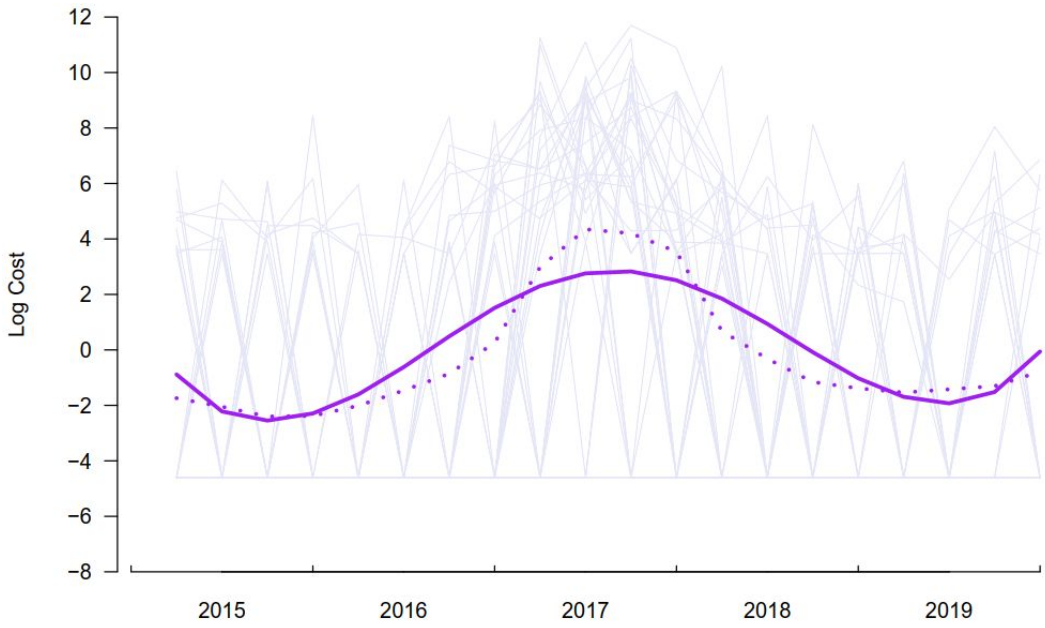
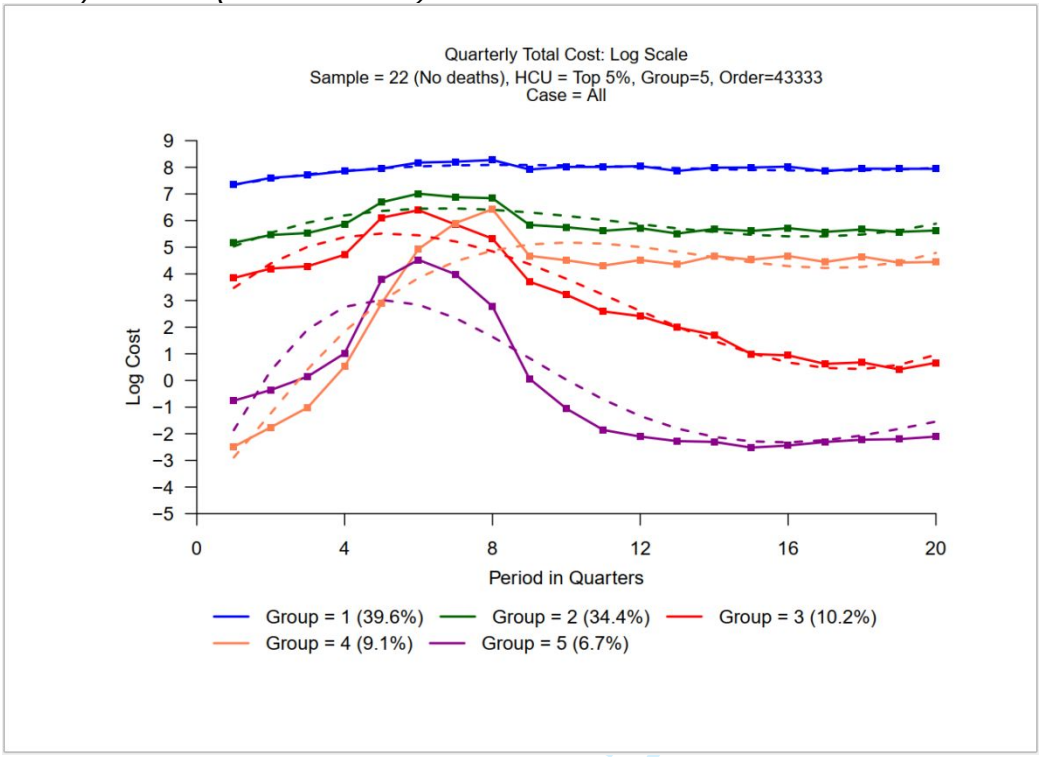


Table A2. Parameters for five-group trajectory model

Group	Parameter	Estimate	SE	t-value	pvalue
Cost spike	Intercept	2.1234	0.0414	51.2940	0.0000
Cost spike	Linear	-4.0860	0.0258	-158.1330	0.0000
Cost spike	Quadratic	0.9875	0.0048	205.4800	0.0000
Cost spike	Cubic	-0.0751	0.0003	-221.7470	0.0000
Cost spike	Quartic	0.0018	0.0000	222.7400	0.0000
Rising cost	Intercept	-3.0978	0.0258	-120.2160	0.0000
Rising cost	Linear	0.3070	0.0106	29.0050	0.0000
Rising cost	Quadratic	0.0768	0.0012	65.9070	0.0000
Rising cost	Cubic	-0.0037	0.0000	-102.8930	0.0000
Declining cost	Intercept	1.2173	0.0329	37.0040	0.0000
Declining cost	Linear	1.3766	0.0129	106.9220	0.0000
Declining cost	Quadratic	-0.1352	0.0014	-94.6240	0.0000
Declining cost	Cubic	0.0030	0.0000	66.4530	0.0000
Persistent high-cost	Intercept	3.6075	0.0166	216.9270	0.0000
Persistent high-cost	Linear	0.4412	0.0055	80.1070	0.0000
Persistent high-cost	Quadratic	-0.0218	0.0006	-36.9620	0.0000
Persistent high-cost	Cubic	0.0002	0.0000	10.2930	0.0000
Persistent very-high-cost	Intercept	6.9499	0.0112	620.3540	0.0000
Persistent very-high-cost	Linear	0.1873	0.0042	44.0910	0.0000
Persistent very-high-cost	Quadratic	-0.0095	0.0005	-20.5020	0.0000
Persistent very-high-cost	Cubic	0.0001	0.0000	7.3060	0.0000

Figure A3. Five-group trajectory model of HNHC patients based on alternative HNHC years (Sensitivity analysis 1)

HNHC year: 2016 (base case: 2017)



HNHC year: 2018 (base case: 2017)

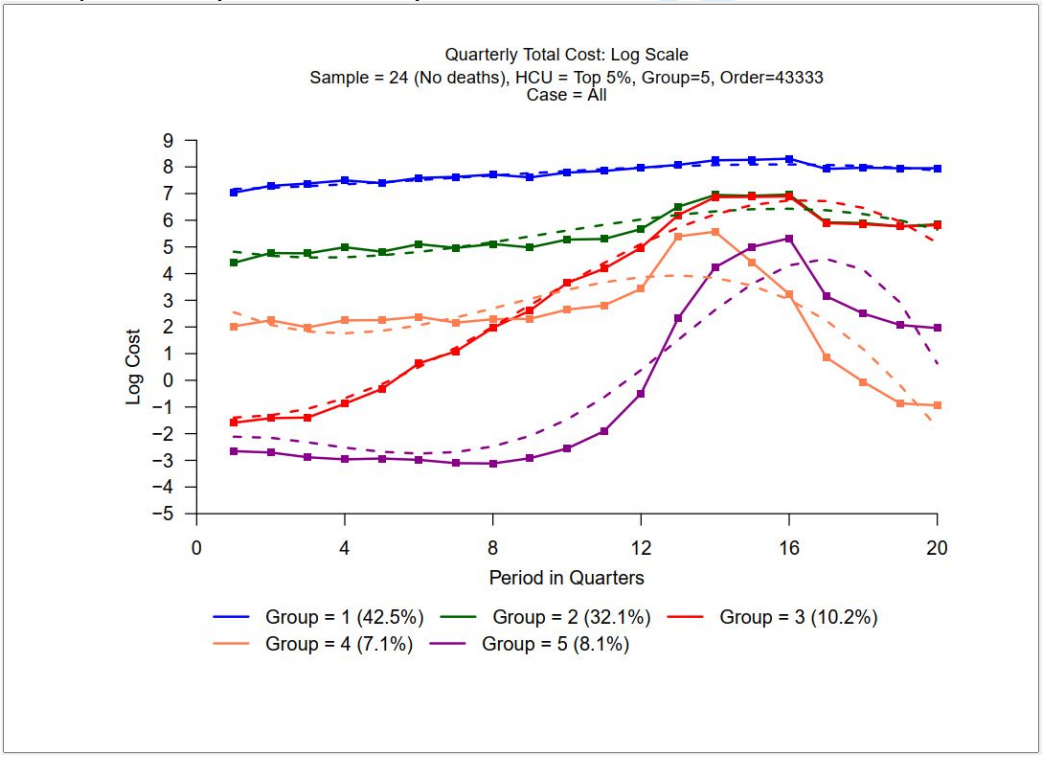
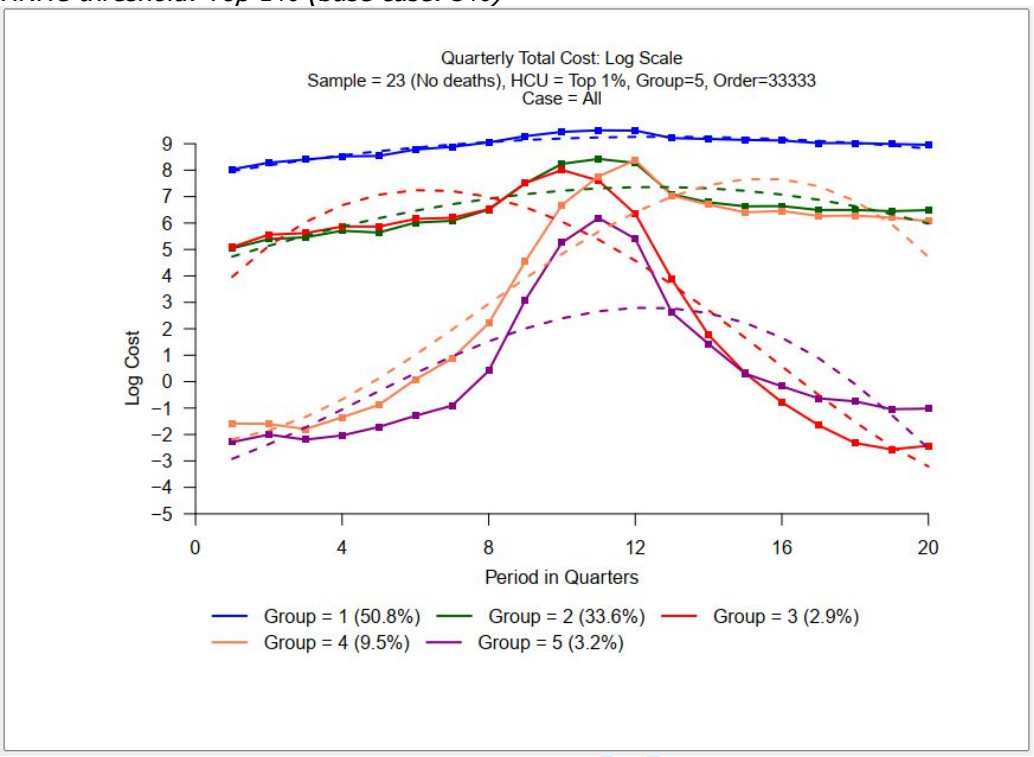


Figure A4. Five-group trajectory model of HNHC patients based on alternative HNHC thresholds (Sensitivity analysis 2)

HNHC threshold: Top 1% (base case: 5%)



HNHC threshold: Top 10% (base case: 5%)

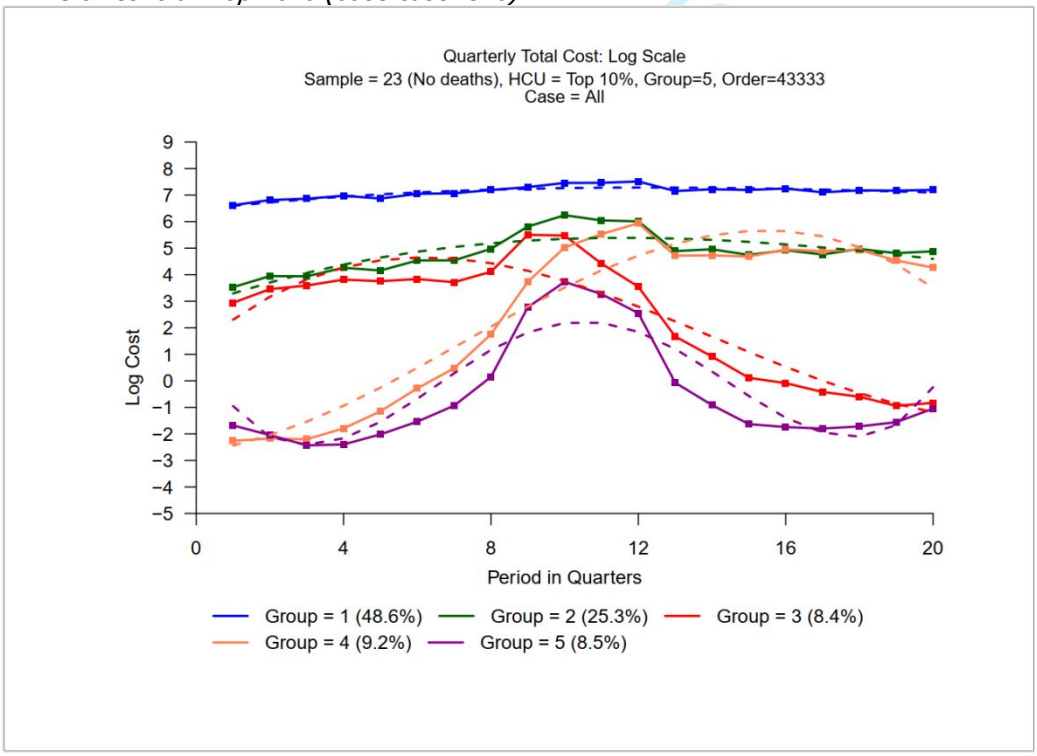


Table A3. Demographic and clinical characteristics (proportion) by trajectory group

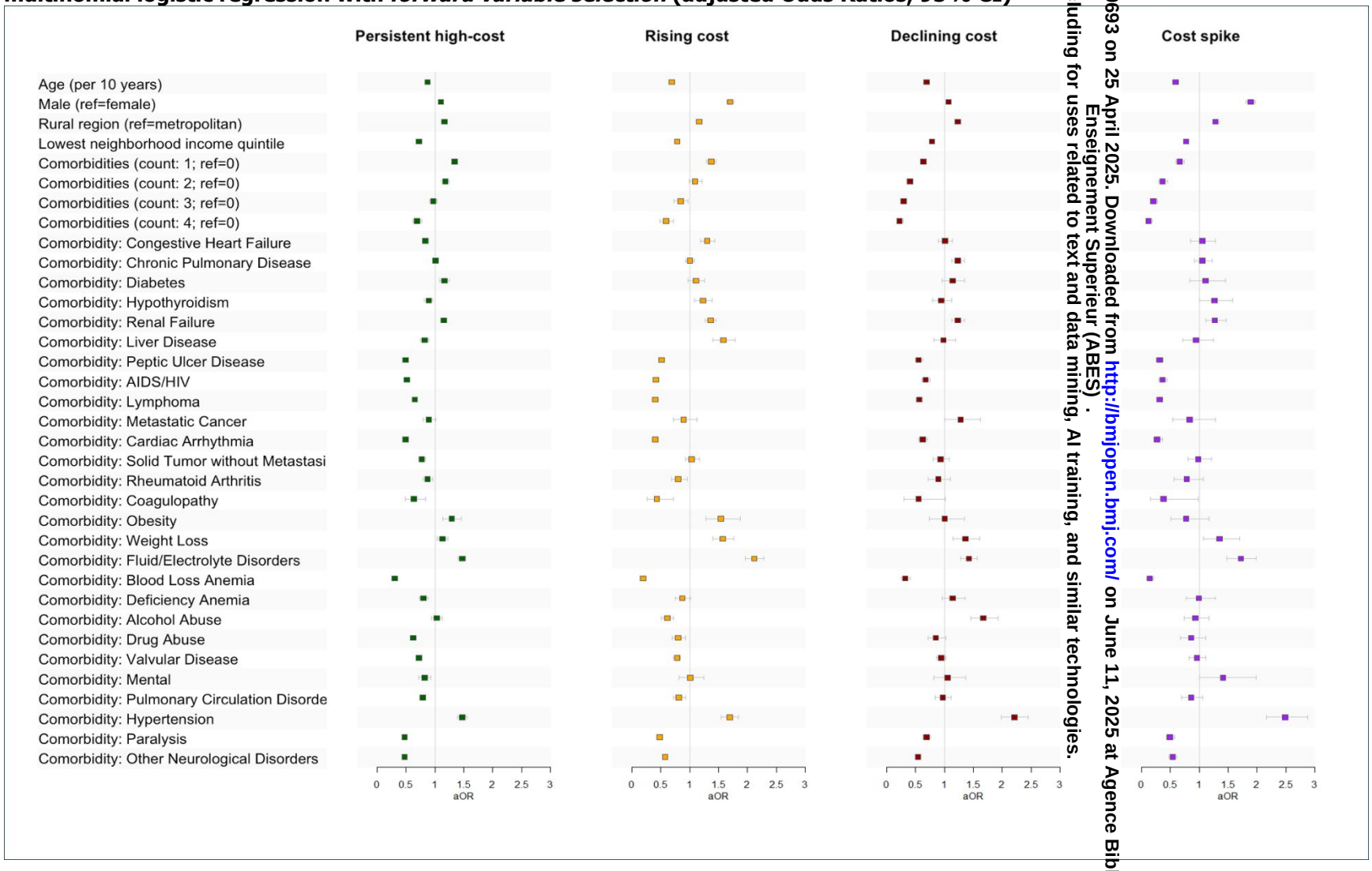
	Persistently very-high-cost	Persistently high-cost	Rising cost	Declining cost	Cost spike
Age Group					
0-44	20.0%	26.0%	44.0%	53.0%	65.0%
45-64	31.0%	34.0%	36.0%	28.0%	26.0%
65-74	20.0%	24.0%	14.0%	11.0%	6.0%
≥75	30.0%	16.0%	6.2%	7.8%	2.1%
Sex					
Male	44.0%	44.0%	51.0%	38.0%	48.0%
Female	56.0%	56.0%	49.0%	62.0%	52.0%
Income Quintile					
1st	28.0%	20.0%	17.0%	21.0%	17.0%
2nd	21.0%	19.0%	16.0%	20.0%	17.0%
3rd	19.0%	19.0%	16.0%	19.0%	16.0%
4th	17.0%	20.0%	16.0%	19.0%	16.0%
5th	14.0%	19.0%	15.0%	17.0%	15.0%
Missing	1.5%	2.4%	21.0%	3.4%	19.3%
Geographic Region					
Metropolitan	56.0%	52.0%	43.0%	51.0%	42.0%
Non-metropolitan (hub hospital)	37.0%	38.0%	30.0%	37.0%	30.0%
Non-metropolitan (small/no hospital)	6.5%	7.8%	7.2%	8.7%	8.4%
Remote	0.2%	0.5%	0.5%	0.6%	0.8%
Missing	0.4%	1.3%	20.0%	2.1%	18.0%
Comorbidities (Elixhauser)					
0	27.0%	40.0%	42.0%	61.0%	68.0%
1	19.0%	28.0%	28.0%	20.0%	20.0%
2	17.0%	16.0%	16.0%	9.4%	7.9%
3	13.0%	8.1%	7.6%	4.7%	2.8%
≥4	24.0%	6.8%	6.8%	5.0%	1.6%

Table A4. Factors associated with group membership (adjusted odds ratio and 95% confidence interval) from multivariate multinomial logistic regression

	Persistently very-high-cost	Persistently high-cost	Rising cost	Declining cost	Cost spike
Age (per 10 years)	*Ref*	0.87 (0.87, 0.88)*	0.69 (0.68, 0.69)*	0.69 (0.68, 0.70)*	0.59 (0.58, 0.60)*
Male (ref: female)		1.10 (1.08, 1.13)*	1.70 (1.64, 1.76)*	1.07 (1.03, 1.11)*	1.89 (1.81, 1.97)*
Rural region (ref: metropolitan)		1.16 (1.13, 1.18)*	1.16 (1.13, 1.20)*	1.23 (1.18, 1.28)*	1.28 (1.23, 1.34)*
Lowest neighborhood income quintile		0.72 (0.70, 0.74)*	0.78 (0.75, 0.81)*	0.78 (0.75, 0.81)*	0.77 (0.74, 0.81)*
Comorbidities (count; ref=0)					
One		1.34 (1.29, 1.39)*	1.37 (1.29, 1.46)*	0.63 (0.59, 0.68)*	0.66 (0.59, 0.74)*
Two		1.18 (1.11, 1.24)*	1.09 (0.99, 1.21)	0.40 (0.36, 0.45)*	0.36 (0.30, 0.45)*
Three		0.97 (0.90, 1.04)	0.84 (0.73, 0.97)*	0.29 (0.25, 0.34)*	0.20 (0.15, 0.27)*
Four		0.69 (0.62, 0.77)*	0.59 (0.48, 0.72)*	0.22 (0.17, 0.28)*	0.12 (0.07, 0.19)*
Comorbidities					
Congestive Heart Failure		0.83 (0.79, 0.88)*	1.30 (1.19, 1.43)*	1.01 (0.89, 1.14)	1.05 (0.85, 1.28)
Chronic Pulmonary Disease		0.51 (0.48, 0.53)*	0.41 (0.37, 0.45)*	0.67 (0.60, 0.75)*	0.36 (0.30, 0.44)*
Diabetes		0.65 (0.63, 0.68)*	0.40 (0.37, 0.43)*	0.56 (0.51, 0.62)*	0.31 (0.26, 0.36)*
Hypothyroidism		0.89 (0.79, 1.01)	0.89 (0.71, 1.12)	1.28 (1.00, 1.62)*	0.84 (0.54, 1.28)
Renal Failure		0.49 (0.46, 0.51)*	0.40 (0.36, 0.45)*	0.62 (0.55, 0.70)*	0.27 (0.21, 0.36)*
Liver Disease		0.77 (0.71, 0.84)*	1.03 (0.92, 1.17)	0.93 (0.80, 1.08)	0.98 (0.80, 1.21)
Peptic Ulcer Disease		0.87 (0.79, 0.96)*	0.80 (0.68, 0.96)*	0.89 (0.71, 1.10)	0.78 (0.56, 1.07)
AIDS/HIV		0.63 (0.48, 0.84)*	0.43 (0.26, 0.71)*	0.55 (0.30, 1.01)	0.38 (0.15, 0.98)*
Lymphoma		1.29 (1.14, 1.46)*	1.54 (1.28, 1.87)*	1.00 (0.74, 1.35)	0.77 (0.51, 1.18)
Metastatic Cancer		1.13 (1.04, 1.22)*	1.57 (1.40, 1.76)*	1.36 (1.15, 1.61)*	1.35 (1.07, 1.70)*
Cardiac Arrhythmia		1.01 (0.97, 1.05)	1.00 (0.93, 1.08)	1.23 (1.12, 1.34)*	1.05 (0.91, 1.22)
Solid Tumor without Metastasis		1.47 (1.40, 1.53)*	2.12 (1.96, 2.28)*	1.42 (1.28, 1.57)*	1.72 (1.48, 1.98)*
Rheumatoid Arthritis		0.30 (0.27, 0.33)*	0.19 (0.15, 0.24)*	0.32 (0.25, 0.41)*	0.14 (0.09, 0.21)*

Coagulopathy		0.80 (0.73, 0.88)*	0.87 (0.75, 1.01)	1.14 (0.96, 1.36)	0.99 (0.77, 1.28)
Obesity		1.03 (0.94, 1.12)	0.61 (0.51, 0.72)*	1.67 (1.45, 1.93)*	0.93 (0.74, 1.17)
Weight Loss		0.62 (0.57, 0.67)*	0.80 (0.69, 0.92)*	0.85 (0.72, 1.02)	0.86 (0.67, 1.11)
Fluid/Electrolyte Disorders		0.72 (0.69, 0.75)*	0.78 (0.72, 0.84)*	0.94 (0.86, 1.03)	0.96 (0.83, 1.11)
Blood Loss Anemia		0.82 (0.72, 0.93)*	1.01 (0.81, 1.24)	1.05 (0.81, 1.36)	1.41 (1.00, 1.98)*
Deficiency Anemia		0.79 (0.74, 0.84)*	0.81 (0.72, 0.92)*	0.97 (0.84, 1.11)	0.86 (0.70, 1.06)
Alcohol Abuse		1.47 (1.39, 1.56)*	1.69 (1.54, 1.84)*	2.21 (1.99, 2.45)*	2.49 (2.16, 2.88)*
Drug Abuse		0.47 (0.44, 0.49)*	0.48 (0.44, 0.52)*	0.69 (0.63, 0.76)*	0.49 (0.43, 0.57)*
Valvular Disease		1.16 (1.08, 1.25)*	1.11 (0.97, 1.26)	1.14 (0.96, 1.36)	1.11 (0.84, 1.46)
Mental		0.47 (0.45, 0.49)*	0.57 (0.53, 0.61)*	0.54 (0.49, 0.59)*	0.54 (0.47, 0.61)*
Pulmonary Circulation Disorders		0.89 (0.82, 0.96)*	1.23 (1.08, 1.39)*	0.94 (0.79, 1.11)	1.26 (1.00, 1.58)*
Hypertension		1.15 (1.11, 1.20)*	1.36 (1.27, 1.46)*	1.23 (1.12, 1.35)*	1.27 (1.11, 1.47)*
Paralysis		0.82 (0.75, 0.89)*	1.58 (1.40, 1.79)*	0.98 (0.81, 1.19)	0.94 (0.72, 1.24)
Other Neurological Disorders		0.49 (0.46, 0.52)*	0.51 (0.46, 0.56)*	0.55 (0.49, 0.63)*	0.31 (0.25, 0.37)*

Figure A5. Forest plot of factors associated with group membership, relative to the 'very-high-cost' trajectory group, from multinomial logistic regression with *forward variable selection* (adjusted Odds Ratios, 95% CI)



BMJ Open

Longitudinal trajectories of health care costs among high-need high-cost patients: A population-based retrospective cohort study in British Columbia, Canada

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2024-089693.R1
Article Type:	Original research
Date Submitted by the Author:	19-Feb-2025
Complete List of Authors:	Trenaman, Logan; University of Washington, Department of Health Systems and Population Health; Centre for Advancing Health Outcomes, St Paul's Hospital Guh, Daphne; Centre for Advancing Health Outcomes, St Paul's Hospital McGrail, Kimberlyn; The University of British Columbia School of Population and Public Health Karim, Ehsan; The University of British Columbia School of Population and Public Health; Centre for Advancing Health Outcomes, St Paul's Hospital Sawatzky, Richard; Trinity Western University School of Nursing; Centre for Advancing Health Outcomes, St Paul's Hospital Bryan, Stirling; The University of British Columbia School of Population and Public Health Li, Linda; The University of British Columbia Department of Physical Therapy; Arthritis Research Centre of Canada, Arthritis Research Canada Parker, Marilyn; Patient Partner Wheeler, Kathleen; Patient Partner Harrison, Mark; UBC Faculty of Pharmaceutical Sciences; The University of British Columbia School of Population and Public Health; Centre for Advancing Health Outcomes, St Paul's Hospital
Primary Subject Heading:	Health economics
Secondary Subject Heading:	Health services research, Health policy
Keywords:	Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Health economics < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Health Care Costs

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Title: Longitudinal trajectories of health care costs among high-need high-cost patients: A population-based retrospective cohort study in British Columbia, Canada

Running Title: Health care cost trajectories

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Keywords: patient-oriented research; health care costs; high-cost users; administrative data; longitudinal studies (MeSH); latent class analysis (MeSH)
Words: 3,388
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Ethical approval: This study was approved by the University of British Columbia Research Ethics Board (H20-00029).
Data availability statement: This analysis was conducted using administrative data from Population Data BC. Access to data provided by the Data Steward(s) is subject to approval, but can be requested for research projects through the Data Steward(s) or their designated service providers. All inferences, opinions, and conclusions drawn in this publication are those of the author(s), and do not reflect the opinions or policies of the Data Steward(s).
Funding: This study was supported by funding from the EuroQol Research Foundation (164-2020RA) and the BC SUPPORT Unit Health Economics and Simulation Modelling Methods Cluster. Logan Trenaman was supported by a Canadian Institutes of Health Research Postdoctoral Fellowship in Patient-Oriented Research. The funders had no role in the study design; the collection, analysis, and interpretation of data; the writing of the manuscript; or the decision to submit the article for publication.
Contributors: LT designed the research and analysis plan in consultation with and using feedback from all the authors. DG and LT conducted the analysis. LT wrote the first draft of the manuscript. All authors contributed to the interpretation of the results and critical revision of the manuscript for important intellectual content and approved the final version. LT is the guarantor of the work and affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as originally planned (and, if relevant, registered) have been explained. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.
Competing interests: All authors have no competing interests to declare.

ABSTRACT

Objectives: We sought to identify groups of high-need high-cost (HNHC) patients with distinct cost trajectories and describe the sociodemographic and clinical characteristics associated with group membership.

Design: A population-based retrospective cohort study, using administrative health data.

Setting: British Columbia, Canada.

Participants: People who were high-need high-cost (HNHC) in 2017, defined as incurring health system costs in the top 5% of the population, and were continuously registered in the Medical Service Plan from January 2015 to December 2019 and alive at the end of the study period.

Outcome measures: The primary objective was to identify longitudinal patterns of health care costs using group-based trajectory modeling. Adopting a health sector perspective, we conducted person-level costing for hospital episodes, day surgeries, physician services, prescription medications, and home and community care services. The secondary objective was to explore sociodemographic and clinical characteristics associated with group membership using adjusted odd-ratios and 95% confidence intervals from a multinomial logistic regression model.

Results: Our final sample comprised 5.4 million British Columbians. In 2017, 161,323 people met our definition of a HNHC and were included in our analysis (threshold: $10,448). We selected a model with five groups. These groups included those with persistently very high-costs (44%, mean five-year total: $124,622); persistent high-costs (32%, mean five-year total: $ 38,997); rising costs (7%, mean five-year total: $43,140); declining costs (10%, mean five-year total: $30,545); and those with a cost spike (7%, mean five-year total: $19,601). Being older, being in the lowest income quintile, and having a greater number of comorbid health conditions were associated with increased odds of being in the persistently very-high-cost trajectory group relative to each other group. There was heterogeneity in the association between individual comorbidities and trajectory group membership. Several comorbidities were associated with a statistically significant increase in the odds of being in the persistently very-high-cost group compared to all other groups (e.g., diabetes; renal failure) whilst others were associated with decreased odds (e.g., metastatic cancer; alcohol abuse).

Conclusion: This study unveils the complex and diverse cost trajectories of HNHC patients in BC, highlighting the necessity for tailored healthcare strategies that address individual patient needs and circumstances. Notably, a high proportion of HNHC patients exhibit persistently high-costs over a five-year period, and available sociodemographic and clinical data are not predictive of group membership. Future

research is needed to develop methods for predicting future HNHC patients before, and to identify evidence-based interventions that can improve patient outcomes and mitigate unnecessary health care utilization and costs.

Strengths and limitations of this study

- This study identified and characterized five cost trajectories of high-need high-cost patients, defined as those incurring costs in the top 5%, among 5.4 million people in British Columbia, Canada.
- We used five-calendar years of health individual-level data from comprehensive, population-based health administrative databases.
- We excluded those who were not continuously insured and those that died during the study period, meaning that our results may not be generalizable to these populations.
- Our costing approach did not capture some health care costs, including prescription drugs obtained during a hospital stay and some specialty drugs related to oncology, transplants, and renal care.
- We relied on health administrative data and thus could not explore the influence of social or behavioral factors on cost trajectories.

1 INTRODUCTION

Health care expenditures are highly concentrated in a relatively small proportion of the population.[1–4] A systematic review of 55 studies found that over half of all health care costs were incurred by just 5% of the population, while nearly a quarter were incurred by 1% of the population.[3] This relatively small segment of the population that incurs a disproportionate amount of health care costs are known as high-need high-cost (HNHC) patients. A substantial amount of research has focused on describing the characteristics of HNHC patients and their health care use.[3] HNHC patients often have multiple chronic conditions and functional limitations, and their risk of being HNHC may be amplified by the presence of other co-occurring health conditions, such as mental illness and substance misuse, and social risk factors, such as homelessness, low socioeconomic status, and food insecurity.[5–9] The relationship between demographic characteristics and HNHC status is less clear,[5] however increasing age and being near the end of life are associated with an increased risk of being a HNHC patient.[3]

While HNHC patients are united in their high health care use, they are a heterogeneous population.[10] Consequently, research has focused on segmenting the population into groups who have similar demographic and clinical profiles.[11–13] For example, Wick *et al.* used latent class analysis to describe groups of persistently high-cost patients, defined as those who were HNHC for two consecutive years. Nine groups were identified, including those characterized by severe mental illness or cardiovascular disease, each of which would need different interventions or supports to improve their care and outcomes.[13]

Given the clinical heterogeneity in HNHC patients, we might expect this to translate into heterogeneity in their costs over time. Selected studies have described the health care use and costs among HNHC patients,[10,14,15] though most have focused on trajectories of costs during the respective high-cost year or during specific episodes of high-cost care.[16] Consequently, the long-term cost trajectories of HNHC patients have not been well characterized.[16–20] Understanding the path to (or from) HNHC status and the factors associated with different trajectories may identify opportunities to intervene to improve patient outcomes and reduce costs.[15] In this study we had two aims, to: 1) identify groups of high-need high-cost patients with distinct cost trajectories, and 2) describe the sociodemographic and clinical characteristics associated with group membership.

2 METHODS

This study was approved by the UBC Behavioural Ethics Research Board (H20-00029). Reporting followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines and the Guidelines for Reporting on Latent Trajectory Studies (GRoLTS) checklist.[21,22]

2.1 Study design and setting

Our study used five calendar years of data from Population Data BC.[23] The data from Population Data BC include longitudinal, person-specific, de-identified health data on BC's 5.4 million residents. This included data from the Discharge Abstract Database (hospital separations, including day surgeries), National Ambulatory Care Reporting System (emergency department), Medical Services Plan (MSP: fee-for-service physician services), PharmaNet database (prescription medications and medical supplies), and Home and Community Care database (long-term care, assisted living, adult daycare, and home care). Our final sample included all British Columbians who were continuously registered in the single-payer public health insurance plan (MSP) from January 2015 to December 2019 and alive at the end of the study period. Additional information on the datasets used in this analysis is available from Population Data BC at https://www.popdata.bc.ca/data.[24]

2.2 Costing

We conducted person-level costing with a health system perspective, following best practice guidelines. For example, inpatient hospitalizations were costed from the Discharge Abstract Database using case-mix costing which involves multiplying the cost of a standard hospital stay by a resource intensity weight.[25] Emergency department care was costed by identifying unique visits using the National Ambulatory Care Reporting System database, Discharge Abstract Database, and Medical Service Plan database, and multiplying each by a ED facility cost for each encounter.[26] Home and community care costs were estimated using the Home and Community Care database, which includes multiplying the number of days in care by an estimated cost per day, which is calculated by dividing residential care expenditures by the total number of residential care days. Lastly, physician and prescription drug costs were obtained directly from the Medical Service Plan and PharmaNet databases, respectively.

We began by aggregating costs at the daily level, with costs spanning multiple days (e.g., hospitalization, 30-day prescription) distributed evenly across the period. Costs were then aggregated at the monthly level. This approach has been used previously, and helps to assess trends over time.[17] Costs were adjusted to 2019 Canadian dollars using the health and personal care component of the Consumer Price Index. We defined HNHC patients as those incurring annual health care costs in the top 5% of the population. In each calendar year of the study period every individual in our sample was classified as either HNHC, or not.

2.3 Statistical analysis

We conducted a descriptive analysis of healthcare costs in our sample over the study period. The standard three-step method identified groups and explored the predictors of class membership.[22] The first step identified the number of unique cost trajectory groups using group-based trajectory modeling (GBTM). The

second step identified the most likely cost trajectory group for everyone, and the third step used a multinomial logistic regression model to investigate covariates associated with membership in each group.

2.3.1 Descriptive analysis

Descriptive analysis focused on describing overall cost characteristics for HNHC patients. We summarized costs (total and by cost category) using descriptive statistics (mean; standard deviation; median; interquartile range)

2.3.2 Identification of cost trajectory groups

Trajectory modeling is widely used in clinical research to understand the change in an outcome over time.[27] Nagin and Odgers identify three different types of trajectory models, including 1) Growth Curve Modeling (GCM), Growth Mixture Modeling (GMM), and Group-Based Trajectory Modeling (GBTM).[27] We chose not to use GCM because it requires an assumption that all individuals in the population follow a similar trajectory,[27] which prior research demonstrates is not a reasonable assumption in the current context.[16] Both GMM and GBTM allow for groups of the population of interest to follow different trajectories,[28] however they differ in that GBTM assumes all individuals within a group follow the same trajectory whereas GMM includes random effects, which is more computationally intensive, but also captures differences in trajectories amongst individuals in the same trajectory group.[28] We chose GBTM over GMM because our focus was on identifying groups of individuals who share similar cost trajectories and could be targeted with tailored policies or interventions. This does not require understanding heterogeneity amongst the different trajectory groups.

Here, we implemented GBTM to identify groups with distinct trajectories of quarterly log-costs (*PROC TRAJ* function in SAS). Our analysis of cost trajectories focused on those who were a HNHC patient in 2017, i.e. the middle year of the study period. The focus on HNHC patients from a single calendar year simplified the analysis. Including participants designated as a HNHC patient in any calendar year would result in users with similar cost trajectories (e.g., a cost spike) that occur in different years being modeled together. This could dilute trends or result in an inflated number of trajectory groups which reflect differential timing rather than unique trajectories. We began by fitting models that include 2 to 10 trajectory groups with up to 4th-order polynomials. We did not consider covariates in the model.[22] We chose our final model and identified the number of trajectory groups using several criteria, including Akaike and Bayesian information criteria (AIC and BIC), log-likelihood, and entropy, visual assessment of the trajectory groups to ensure that they were distinct from each other, and evaluating the posterior probability of group membership to ensure it exceeded a minimal threshold of >0.7.[27] We conducted sensitivity analyses to explore the impact of modeling decisions on our results. This included exploring the impact of different samples (e.g., HNHC in 2016; 2018), threshold definitions of HNHC patients (top 1%; top 10%), and ways of modeling cost

(monthly costs; rolling costs). We assumed that resource use and cost data were comprehensive, thus, there were no missing data for our GBTM analysis.

2.3.3 Characteristics associated with trajectory group membership

We explored the association between time stable sociodemographic and clinical covariates and group membership using a multinomial logit model.[27] The model included age, sex, urban area (rural versus metropolitan), neighborhood income quintile, and comorbid conditions as measured using the Elixhauser Comorbidity Index.[29] Age, sex, urban area, and neighborhood income quintiles were measured using data from the first year of our analysis (2015). All 30 comorbidities in the index were measured across the five-year study period (2015-2019) and dichotomized as either present or absent. We also included a variable which counted the total number of comorbidities and categorized individuals as having either 0, 1, 2, 3, and 4 or more comorbid conditions. Model selection was conducted using stepwise backward variable selection, and we chose the best model based on the AIC. As a sensitivity analysis we also conducted variable selection using stepwise forward variable selection. We assumed that our data on comorbidities were comprehensive (i.e., no missingness) however there were missing demographic data. Given the small relatively small proportion of missingness, we conducted a complete case analysis to identify the characteristics associated with trajectory group membership.

2.4 Patient and Public Involvement

Two patient partners (MP; KW) were members of the research team. There contributions included outlining the research questions, participating in all team meetings, providing feedback on the analysis plan, and reviewing and providing critical feedback on the manuscript and other dissemination materials including conference abstracts and presentations. Their feedback was critical in the decision to use the GBTM methodology. They felt it was important to explore the longitudinal cost trajectories of people who transition to or from HNHC status, and that the graphical output provided by GBTM was a more intuitive way to engage with the results.

3 RESULTS

Our final sample comprised 5.4 million persons. The cumulative distribution of health care expenditures by the percent of the population is presented in Figure 1. We found that in 2017 approximately 27% of British Columbians incurred no health care costs, while the top 10%, 5%, and 1% accounted for 79%, 67%, and 36% of health care expenditures, respectively. Over 224,000 British Columbians met our definition of being a HNHC patient in 2017 (cost threshold to be in the top 5% was $7,968). Of these individuals, 39% were HNHC in one-year (2017), while 21%, 15%, 10%, 15% were HNHC for two-, three-, four-, and five-years, respectively. Compared to the British Columbia (BC) population, HNHC patients tended to be older, were more likely to be female, and to have a higher number of comorbid conditions (see Table 1).

3.1 Identification of cost trajectory groups

GBTM results for four to seven trajectory groups are presented in the Appendix (Figure A1), while model fit statistics are available in Table A1. We selected a five-group model of cost trajectories. The average and predicted values (including 95% confidence intervals) of the five-group model are available in Appendix Table A2. Figure 2 plots the mean actual (solid line) and predicted trajectories (dashed line) for each group. The groups included 1) persistent very-high-cost (44.0%), 2) persistent high-cost (31.8%), 3) rising cost (10.3%), 4) declining cost (7.1%) and 5) those exhibiting a cost spike (6.8%). All told, over three quarters of HNHC patients were associated with a persistent very-high-cost or high-cost trajectory group. The mean trajectories for each group alongside individual trajectories (1% sample) are presented in Appendix Figure A2 while the model parameters are described in Table A3. Sensitivity analyses found similar trajectory groups in HNHC patients from the prior or following year (Figure A3) and for different HNHC thresholds (Figure A4).

Table 2 describes the cumulative cost profile of each of the five trajectory groups over the five-year study period. On average, those in the persistent very-high-cost trajectory group incurred the highest costs (mean: $124,622, SD = $92,700; median: $85,735, IQR = $52,305 to $148,838). In contrast, those in the cost-spike trajectory group incurred the lowest costs, (mean: $19,601, SD = $5,181; median: $13,828, IQR = $10,976 to $20,112).

3.2 Characteristics associated with trajectory group membership

The distribution of observable patient characteristics by trajectory group is available in Appendix Table A4. The results of the multinomial logit model estimated using stepwise backward variable selection (adjusted odds ratios and 95% confidence intervals) are presented in Figure 3 and Appendix Table A5. Of all the variables considered, all but one comorbidity indicator from the Elixhauser index (peripheral vascular disorders) was retained in the final model following stepwise backward variable selection. Membership in the persistently very-high-cost trajectory group was associated with increased odds of being older, living in a metropolitan (rather than non-metropolitan) area, and a neighborhood with lower average household income. With respect to comorbid conditions, those associated with a persistently very-high-cost trajectory group had increased odds of reporting a greater number of comorbid conditions. There were increased odds of most comorbid conditions in the persistently very-high-cost group relative to the other groups, including the persistent high-cost trajectory group. Some notable results include that the persistently high-cost trajectory group was associated with decreased odds of common ambulatory care sensitive conditions, including congestive heart failure, chronic pulmonary disease, and diabetes. In contrast, being in the persistent very-high-cost trajectory group was associated with decreased odds of hypertension, alcohol abuse, and metastatic and non-metastatic cancers, relative to the other four trajectories. The overall fit of the model as measured by McFadden's pseudo-R^2, which represents the proportion of variance in the

dependent variable that is explained by the independent variables, was 0.1 (Nagerkerke R^2=0.16). Our sensitivity analysis using stepwise forward variable selection using AIC resulted in the same model specification as stepwise backward variable selection. Results from the stepwise forward variable selection process are presented as a forest plot in Appendix Figure A5.

4 DISCUSSION

The study described the five-year health care cost trajectories of HNHC patients in BC, Canada, using comprehensive, population-based administrative databases. We found that HNHC patients exhibit heterogeneous longitudinal cost trajectories, however three quarters of HNHC patients were associated with either a persistent high-cost or persistent very-high-cost trajectory. This demonstrates that for many HNHC individuals costs remain elevated and stable over time. We found that being in the persistent very-high-cost trajectory was associated with several factors, including older age, lower socioeconomic status, and multimorbidity.

There have been few applications of GBTM to model health care costs, often near the end of life and/or in specific clinical populations.[17,18,30–34] For example, Teraoka *et al.* used GBTM to explore health care costs for older adults in Japan in the final five-years of life.[32] They found that nearly three quarters of their sample was associated with the two most common trajectories, including persistent-high costs (46%) and persistent medium-to-high costs (26%). We had similar findings despite excluding those who died during the study period. Placona *et al.* explored latent cost trajectories of HNHC Medicare patients.[16] Despite being conducted in a different health care setting, using a different clustering method (k-means), definition of HNHC (top 10%), and length of analysis (three years), there were similarities to our findings. For example, Placona *et al.* identified three distinct cost trajectories in four and five group models (persistent high-cost; rising cost; and episodic high-cost) which closely mirror our own findings. They also found a high proportion of patients who were persistently high-cost across the study period (51%). Collectively, these results suggest that persistent high costs are a hallmark of the HNHC population. We found that over 60% of all HNHC patients in BC were under 65 years of age, and 39% had two or more comorbidities, as measured by the Elihxauser comorbidities index. In contrast, Guilcher *et al.* used Ontario administrative data from 2010/11 and found that a smaller proportion of the HNHC population was under 65 (48%) while nearly 59% had eight or more distinct comorbid conditions.[35] These discrepancies may reflect differences in the underlying population, time trends, or in the case of comorbidities, the specific indices used.

We conducted an analysis to determine which sociodemographic and clinical factors were associated with group membership. We found that being in the persistent very-high-cost group was associated with increased odds of being older and the presence of multiple comorbidities, both factors that have been identified previously.[3,5] However, there was heterogeneity in the relationship between specific comorbidities

and cost trajectory groups. For example, several comorbidities were associated with a statistically significant increase in the odds of being in the persistently very-high-cost group compared to all other trajectory groups, including chronic obstructive pulmonary disease, diabetes, renal failure, AIDS/HIV, and rheumatoid arthritis. Conversely, diagnoses of both metastatic and non-metastatic cancer and alcohol abuse were associated with a statistically significant decrease in odds of being in the persistently very-high-cost group compared to all other trajectory groups.

We found that the overall fit of our multinomial model, as measured by McFadden's pseudo-R^2, was 0.1. Lee et al., found similar results when investigating the relationship between demographic and clinical predictors and hospitalization trajectories amongst HNHC patients (pseudo-R^2 range= 0.03-0.07),[20] as did Schneider *et al.*, despite focusing on a more clinically homogeneous population (people with advanced breast cancer at the end of life) and having access to patient hospital records which included detailed information on treatment[17] Importantly, McFadden's pseudo-R^2 has been demonstrated to be lower than other commonly used measures of R^2, with 0.2 to 0.4 "indicative of extremely good model fits" and "equivalenced to 0.7 to 0.9 for a linear function."[36] Regardless, the value obtained from our model falls outside this range, suggesting that there are other unknown variables, not included in this analysis, which may predict the cost trajectory groups. Previous research has highlighted the association between social factors and health behaviors and HNHC status.[7,8] However, we did not have comprehensive data on these factors. For example, we lacked an indicator for housing insecurity, relied on a proxy for socioeconomic status (neighborhood income quintile), and did not have information on self-reported health status, smoking status, or level of physical activity.

There are several clinical and policy implications of this work. Our results suggest that a considerable portion of HNHC patients incur persistently high health care costs, and these patients have high rates of multimorbidity. For example, nearly a quarter of patients associated with the persistent very-high-cost group had four or more comorbid conditions as measured by the Elixhauser index. There have been relatively few studies evaluating the impact of interventions targeting those with multimorbidity, with those that are available reporting either mixed results.[37] That said, we found evidence that several prevalent ambulatory care sensitive conditions (ACSC) associated with the persistent very-high-cost trajectory group, including chronic heart failure, COPD, and diabetes. Given that ACSCs are defined as conditions whereby timely and effective primary and outpatient care can reduce the risk of subsequent hospitalization,[38] identifying and targeting individuals who incur persistently high costs for ACSC is one potential area to improve outcomes and reduce costs. Wick et al. identified several interventions that could support improve care and outcomes for different high-cost patient populations, including increased access to specialty out-patient clinics for cardiac and pulmonary care, encouraging the use of home hemodialysis for those with

advanced kidney disease, and improving community care for those with substance use disorders or severe mental health conditions.[13]

We also found that lower SES was associated with increased odds of being in the persistent very-high-cost trajectory. This is consistent with previous Canadian research that demonstrated that future high-cost health care use is strongly associated with SES, including income, housing, food security, and education.[7] This emphasizes that polices that target the social determinants of health, such as providing income support or access to affordable housing, have the potential to mitigate high health care utilization. Finally, our analysis has highlighted the limitations of administrative health data in capturing information on the social determinants of health, and the importance of improving the collection of these data so we can better understand their influence on health outcomes and health care use. This underscores the importance of efforts by groups like the World Health Organization, Healthy People 2030, and Canada Infoway, who are spearheading efforts to improve the routine collection of data on the social determinants of health.[39–41]

There are several strengths and limitations that warrant consideration. The strength of this study is that it uses health administrative databases, and as such, we have a large, representative sample of the BC population and comprehensive data on resource use and health system costs. Another strength is that we used five years of data which provides insight into how people transition to and from HNHC status. Our decision to focus on data from 2015–2019 was intentional and based on several key considerations. The COVID-19 pandemic caused unprecedented disruptions in health care utilization and costs, introducing variability that may not reflect stable, long-term cost trajectories. Including pandemic-era data could distort findings by introducing spurious trends that do not accurately represent typical cost patterns among HNHC patients. There are also some limitations. First, we excluded those who were not continuously enrolled in MSP, or those that died during the five-year study period, meaning that our analysis may not be generalizable to these populations. Secondly, our costing approach did not capture some costs. For example, the PharmaNet database does not capture prescription drugs obtained during a hospital stay, or those administered through the BC Cancer Agency (i.e., oncology medications such as chemotherapy drugs), BC Transplant society (i.e., transplant-related drugs), or BC renal agency (i.e., drugs for kidney dialysis). Lastly, relying on administrative data alone means we could not explore the relationship between some demographic (e.g., race/ethnicity) and social and behavioral factors on cost trajectories. This could be accomplished by using linked survey data; however, this would dramatically reduce the sample size available for analysis.

4.1 Conclusions

HNHC patients in British Columbia exhibit heterogeneous longitudinal cost trajectories; however, a high proportion are associated with persistent costs over a five-year period. Multimorbidity is a hallmark of

persistent very-high-costs, however, available socio-demographic and clinical data do not predict who is likely to be associated with different cost trajectories. Future work is needed to differentiate between preventable and non-preventable health care costs, develop methods for predicting people at-risk of becoming HNHC, and to identify interventions that can improve outcomes and reduce costs.

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Table 1. Characteristics of high-need high-cost (HNHC) patients (top 5%) and the BC general population

	HNHC (top 5%) N=224,285		BC N=5,378,411	
	N	%	N	%
Age Group				
0-44	66,789	29.8%	3,211,043	59.7%
45-64	71,159	31.7%	1,459,001	27.1%
65-74	42,228	18.8%	442,627	8.2%
≥75	44,109	19.7%	265,659	4.9%
Missing	0	0.0%	81	0.0%
Sex				
Male	99,441	44.3%	2,670,537	49.7%
Female	124,837	55.7%	2,707,240	50.3%
Missing	7	0.0%	634	0.0%
Income Quintile				
1st	51,291	22.9%	896,900	16.7%
2nd	44,100	19.7%	903,394	16.8%
3rd	41,049	18.3%	908,806	16.9%
4th	39,893	17.8%	915,124	17.0%
5th	36,512	16.3%	873,204	16.2%
Missing	11,440	5.1%	880,983	16.4%
Geographic Region				
Metropolitan	117,296	52.3%	2,707,890	50.3%
Non-metropolitan (hub hospital)	80,899	36.1%	1,499,898	27.9%
Non-metropolitan (small/no hospital)	16,302	7.3%	325,156	6.0%
Remote	903	0.4%	16,590	0.3%
Missing	8,885	4.0%	828,877	15.4%
Comorbidities (Elixhauser)				
0	85,185	38.0%	4,815,139	89.5%
1	51,562	23.0%	312,107	5.8%
2	34,610	15.4%	129,128	2.4%
3	21,457	9.6%	59,972	1.1%
≥4	31,471	14.0%	62,065	1.2%

Figure 1. Distribution of health care expenditures in British Columbia in 2017

Figure 2. Actual (solid line) and predicted (dashed line) five-year cost trajectories from the five-group trajectory model of 2017 high-need high-cost patients (top 5%) in BC, Canada

Table 2. Five-year costs of high-need high-cost patients (top 5%) by trajectory group

		Persistent very-high-cost (44.0%)	Persistent high-cost (31.8%)	Rising cost (10.3%)	Declining cost (7.1%)	Cost spike (6.8%)
	N	99,122	71,095	22,998	15,99	15,177
Total Cost	Mean (SD)	$124,622 ($92,700)	$38,997 ($19,841)	$43,140 ($17,426)	$30,44 ($9,24	$19,601 ($5,181)
	Median (IQR)	$85,735 ($52,305, $148,838)	$28,259 ($20,097, $44,747)	$24,973 ($16,594, $47,846)	$19,62 ($14,288, $31,6	$13,828 ($10,976, $20,112)
Inpatient Care	Mean (SD)	$39,604 ($39,562)	$20,954 ($15,479)	$24,915 ($13,150)	$16,40 ($6,64	$12,715 ($4,533)
	Median (IQR)	$20,225 ($6,363, $48,792)	$12,987 ($8,022, $23,703)	$12,484 ($7,584, $25,840)	$9,22 ($6,233, $17,0	$8,441 ($5,898, $12,887)
Physician Services	Mean (SD)	$18,433 ($49,800)	$11,017 ($3,037)	$9,111 ($2,021)	$7,83 ($1,24	$4,755 ($741)
	Median (IQR)	$15,311 ($9,845, $22,428)	$10,014 ($7,487, $13,292)	$7,513 ($5,379, $10,851)	$6,36 ($4,886, $9,0	$4,320 ($2,970, $5,962)
Prescription Drugs	Mean (SD)	$25,570 ($27,293)	$3,461 ($6,650)	$4,004 ($4,408)	$3,81 ($3,4	$839 ($1,640)
	Median (IQR)	$9,904 ($2,091, $31,171)	$58 ($0, $1,487)	$0 ($0, $1,034)	$0 ($0, $2	$0 ($0, $0)
Emergency Department	Mean (SD)	$4,109 ($4,424)	$2,140 ($1,559)	$1,977 ($884)	$1,91 ($7	$1,129 ($362)
	Median (IQR)	$2,163 ($1,081, $4,686)	$1,442 ($721, $2,523)	$1,081 ($721, $2,523)	$1,08 ($360, $2,1	$721 ($360, $1,442)
Home and Community Care	Mean (SD)	$36,906 ($65,782)	$1,426 ($5,636)	$3,133 ($7,018)	$1,11 ($3,5	$163 ($397)
	Median (IQR)	$0 ($0, $15,266)	$0 ($0, $0)	$0 ($0, $0)	$0 ($0, $0)	$0 ($0, $0)

IQR: interquartile range; SD: standard deviation

Figure 3. Forest plot of factors associated with group membership, relative to the 'very high-cost' trajectory group, from multinomial logistic regression (adjusted Odds Ratios, 95% CI)

aOR: adjusted odds ratio; CI: confidence interval

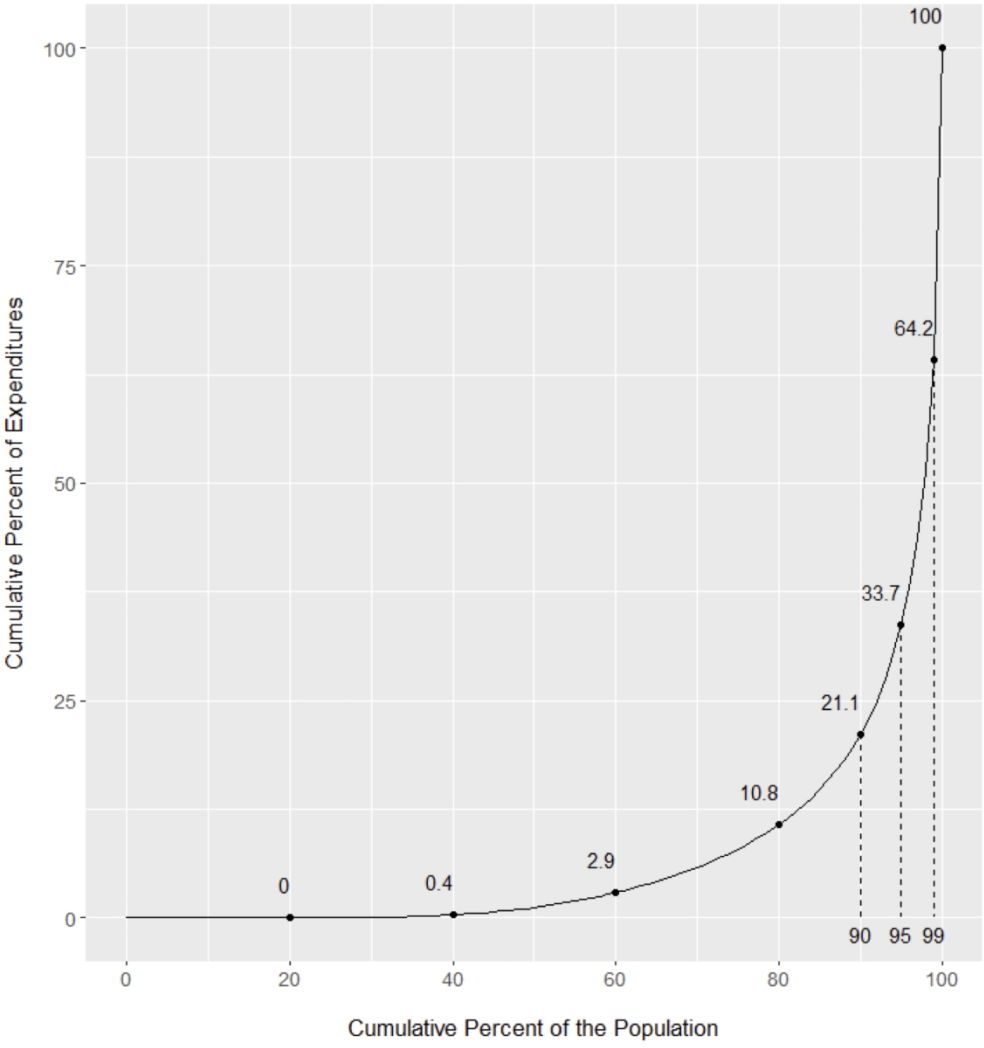

Figure 1. Distribution of health care expenditures in British Columbia in 2017

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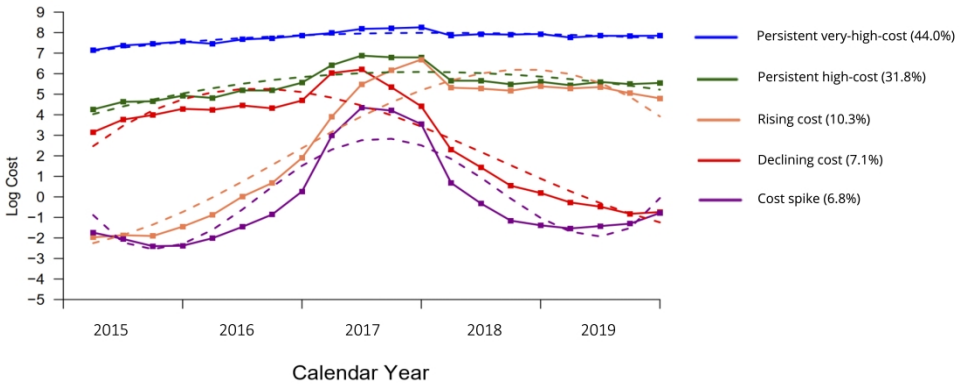

Figure 2. Actual (solid line) and predicted (dashed line) five-year cost trajectories from the five-group trajectory model of 2017 high-need high-cost patients (top 5%) in BC, Canada

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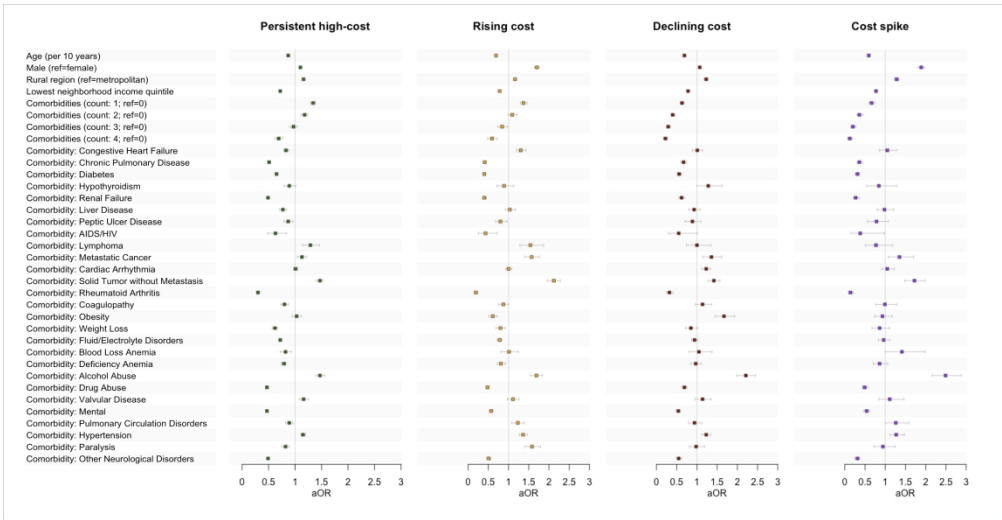

Figure 3. Forest plot of factors associated with group membership, relative to the 'very-high-cost' trajectory group, from multinomial logistic regression (adjusted Odds Ratios, 95% CI)

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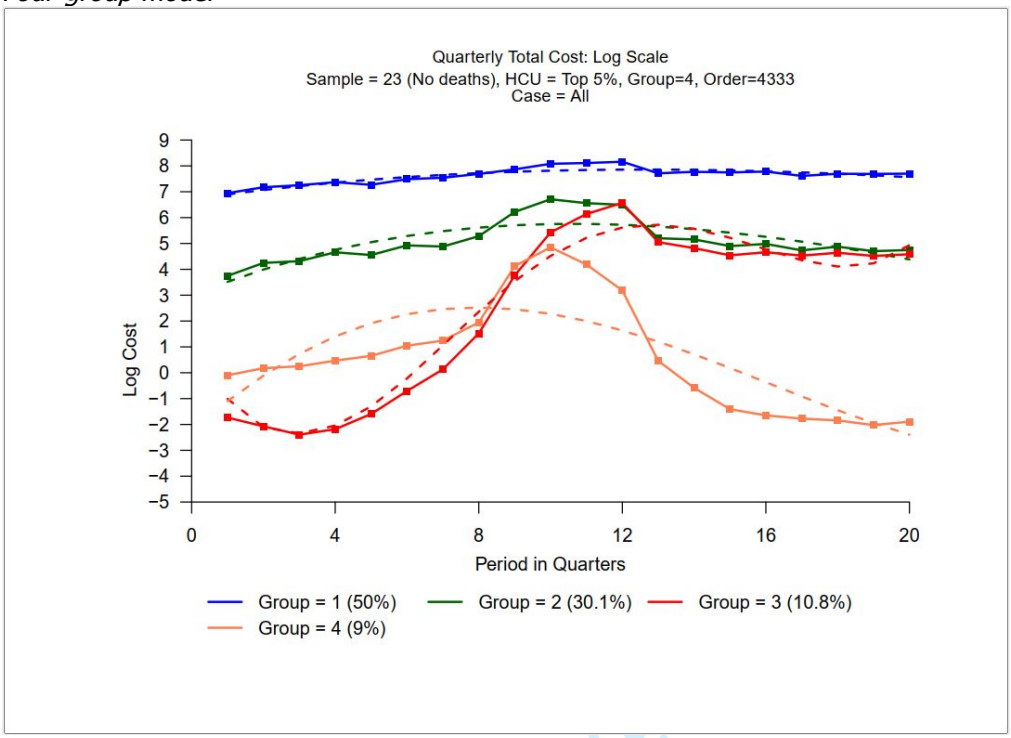
Appendix

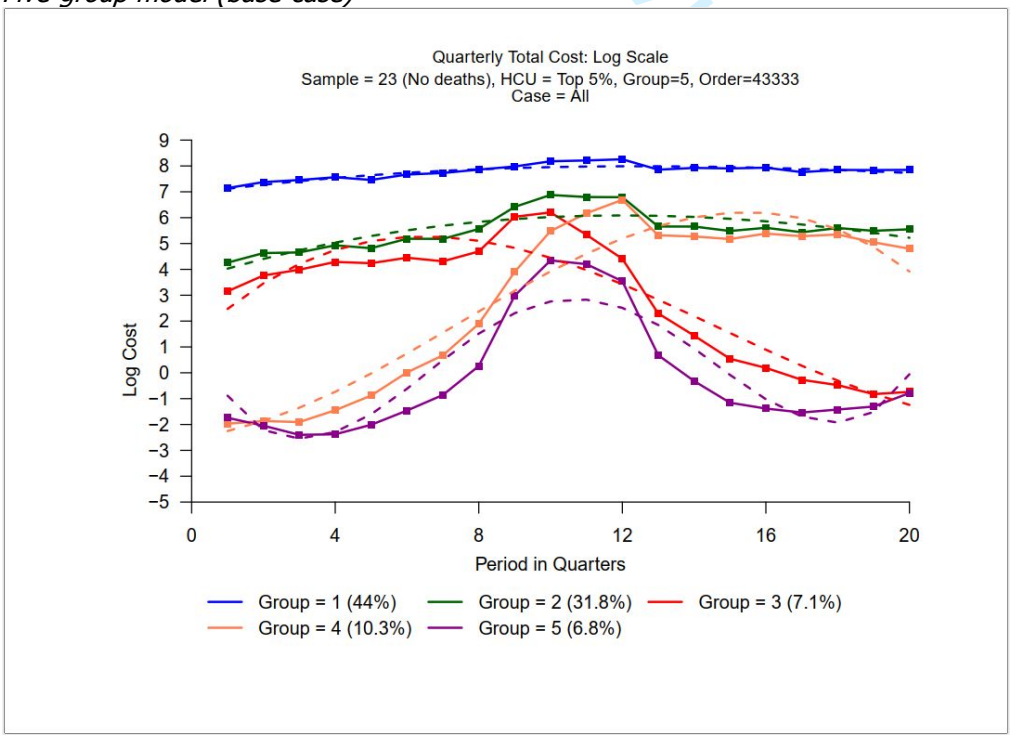
- Figure A1. Actual (solid line) and predicted (dashed line) five-year cost trajectories from group-based trajectory models with four to seven latent groups
- Table A1. Model fit statistics for group-based trajectory models with four to seven latent groups
- Table A2. Table A2. Average and predicted values (with 95 % confidence intervals) for the five-group trajectory model, by time period
- Figure A2. Mean trajectories for each latent group alongside individual trajectories (1% sample)
- Table A3. Parameters for five-group trajectory model
- Figure A3. Five-group trajectory model of HNHC patients based on alternative HNHC years (Sensitivity analysis 1)
- Figure A4. Five-group trajectory model of HNHC patients based on alternative HNHC thresholds (Sensitivity analysis 2)
- Table A4. Demographic and clinical characteristics by trajectory group
- Table A5. Factors associated with group membership (adjusted odds ratio and 95% confidence interval) from multivariate multinomial logistic regression
- Figure A5. Forest plot of factors associated with group membership, relative to the 'very-high-cost' trajectory group, from multinomial logistic regression (adjusted Odds Ratios, 95% CI)

Figure A1. Actual (solid line) and predicted (dashed line) five-year cost trajectories from group-based trajectory models with four to seven latent groups

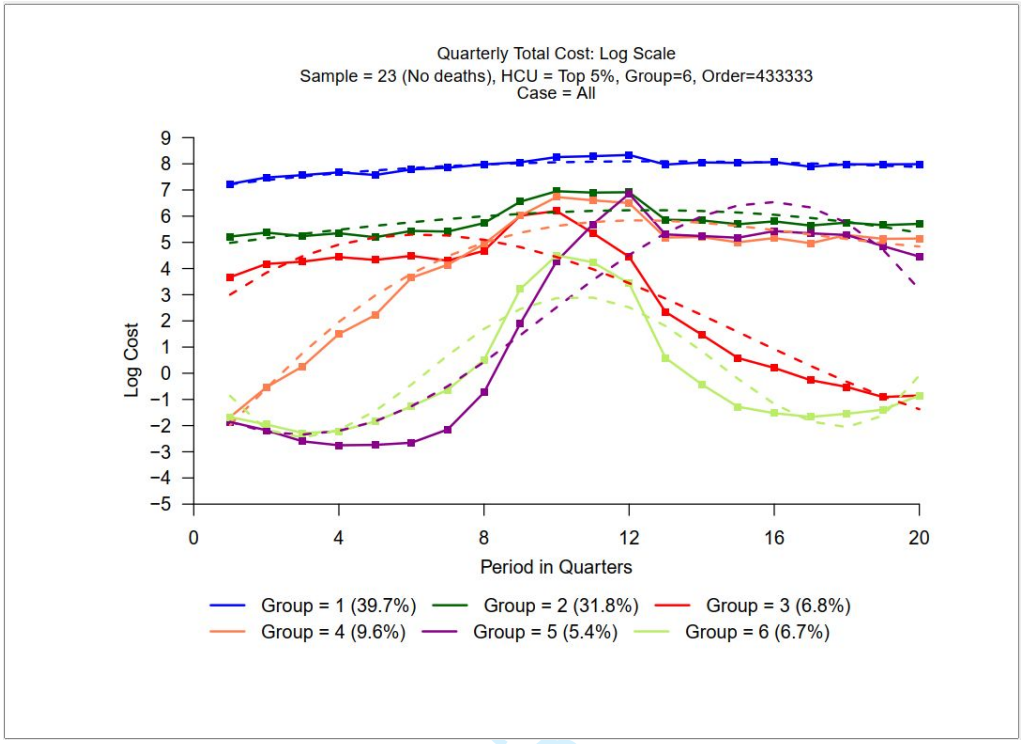
Four-group model



Five-group model (base-case)



Six-group model



Seven-group model

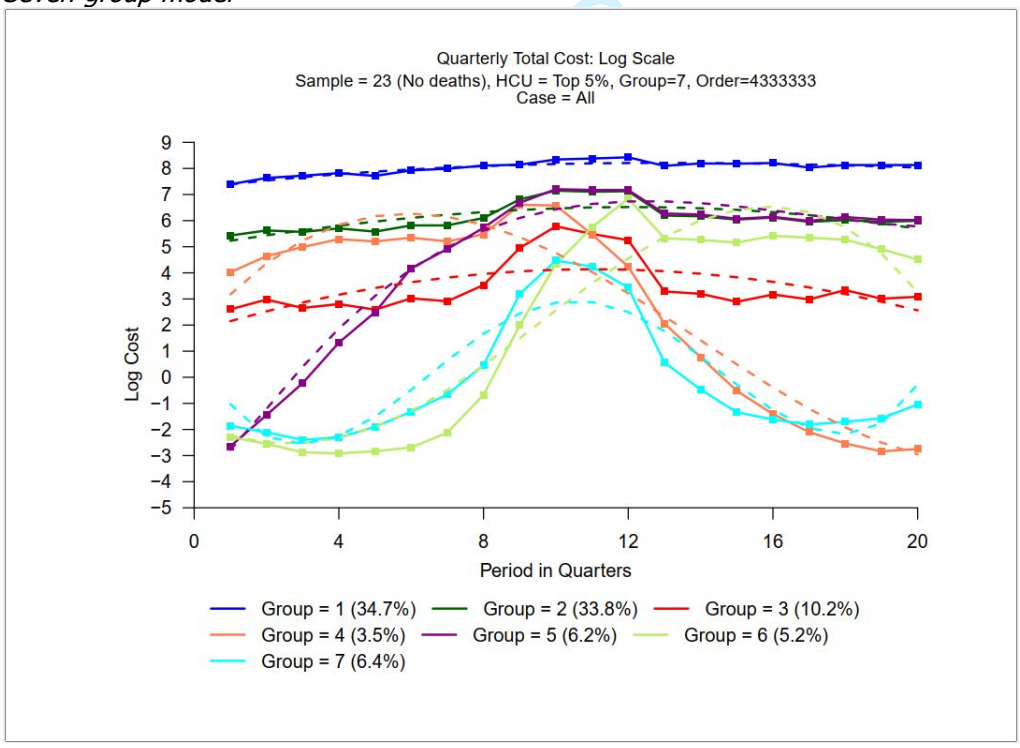


Table A1. Model fit statistics for group-based trajectory models with four to seven latent groups and 2nd to 4th degree polynomials*

groups	polynomials	BIC1	BIC2	AIC	LL	Change in BIC1	Change in BIC2	Entropy
4	4333	-11550175	-11550206	-11550066	-11550045			0.903
5	**43333**	**-11472689**	**-11472728**	**-11472555**	**-11472529**	**23891**	**23890**	**0.898**
6	433333	-11433127	-11433174	-11432967	-11432936	25155	25154	0.889
7	4333333	-11401437	-11401491	-11401252	-11401216	24995	24974	0.883

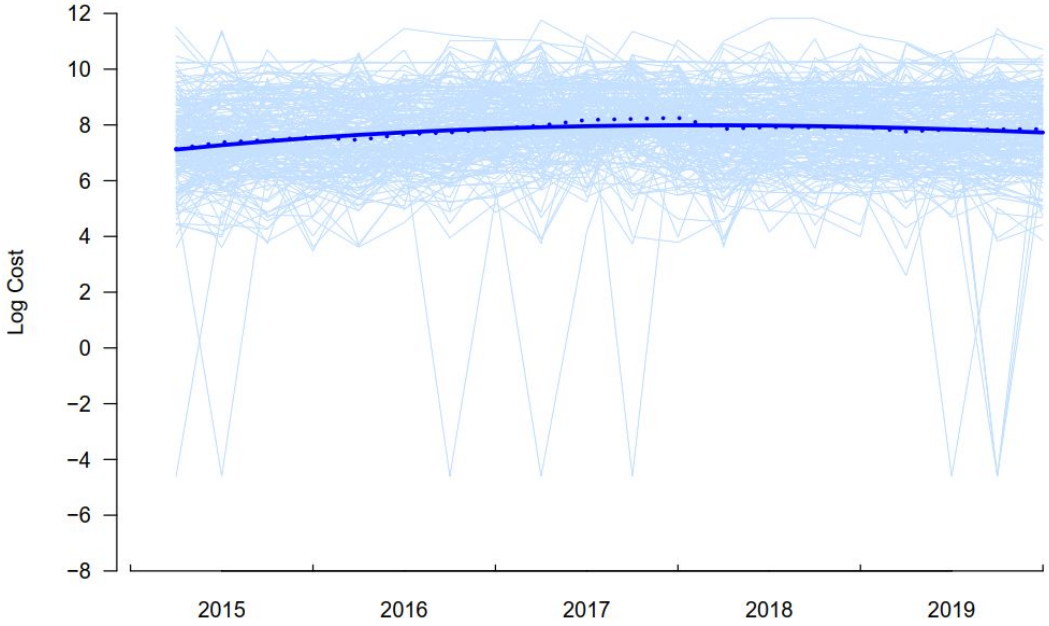
AIC: Akaike information criteria; BIC: Bayesian information criteria; LL: log-likelihood
* bolded model was selected as the base case

Table A2. Average and predicted values (with 95 % confidence intervals) for the five-group trajectory model, by time period

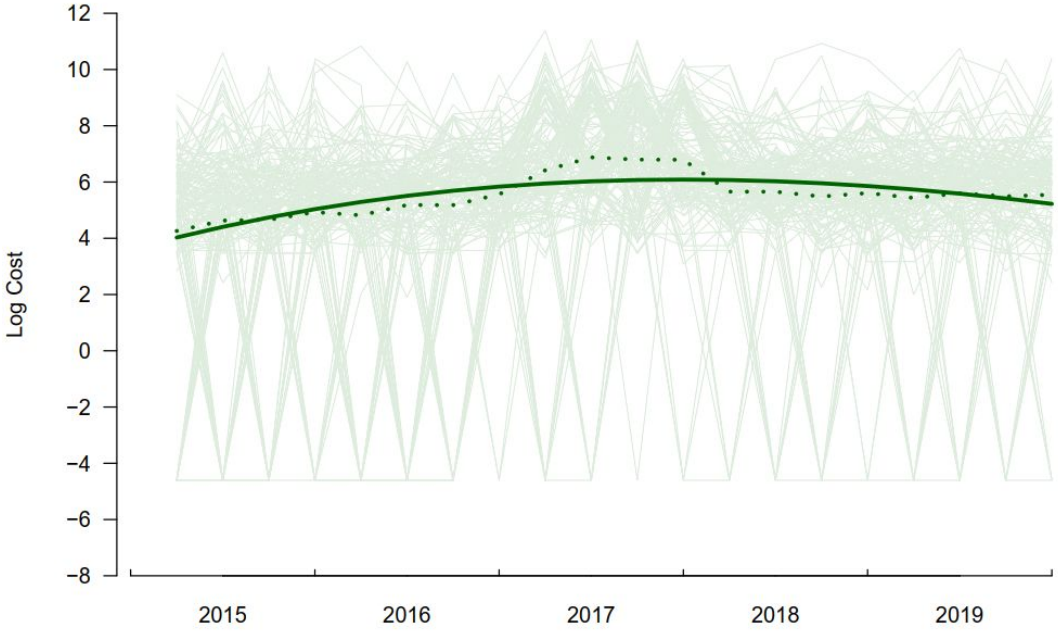
Time period	Persistent very-high cost				Persistent high cost				Rising cost				Declining cost				Cost spike			
	Avg.	Pred.	2.5%	97.5%	Avg.	Pred.	2.5%	97.5%	Avg.	Pred.	2.5%	97.5%	Avg.	Pred.	2.5%	97.5%	Avg.	Pred.	2.5%	97.5%
1	7.14	7.12	7.10	7.13	4.26	4.03	4.00	4.05	-1.97	-2.25	-2.29	-2.21	3.15	2.47	2.42	2.52	-1.74	-0.89	-0.95	-0.82
2	7.38	7.27	7.26	7.29	4.63	4.40	4.38	4.43	-1.87	-1.86	-1.90	-1.83	3.76	3.46	3.43	3.49	-2.05	-2.22	-2.25	-2.18
3	7.46	7.41	7.40	7.42	4.65	4.74	4.72	4.76	-1.91	-1.35	-1.38	-1.32	3.99	4.21	4.18	4.24	-2.40	-2.55	-2.58	-2.52
4	7.56	7.54	7.53	7.55	4.93	5.03	5.02	5.05	-1.45	-0.74	-0.77	-0.70	4.29	4.75	4.72	4.78	-2.38	-2.29	-2.33	-2.26
5	7.46	7.64	7.63	7.65	4.82	5.29	5.28	5.31	-0.88	-0.03	-0.06	0.00	4.24	5.09	5.06	5.12	-2.01	-1.61	-1.64	-1.57
6	7.67	7.73	7.72	7.74	5.18	5.51	5.49	5.52	0.01	0.74	0.71	0.77	4.45	5.25	5.22	5.28	-1.46	-0.62	-0.65	-0.58
7	7.73	7.81	7.80	7.82	5.18	5.69	5.68	5.70	0.67	1.55	1.53	1.58	4.31	5.25	5.22	5.28	-0.86	0.49	0.46	0.52
8	7.86	7.87	7.86	7.88	5.56	5.84	5.82	5.85	1.90	2.37	2.35	2.39	4.69	5.10	5.07	5.13	0.26	1.51	1.49	1.54
9	7.98	7.92	7.91	7.93	6.42	5.95	5.93	5.96	3.90	3.17	3.15	3.19	6.03	4.83	4.80	4.85	2.98	2.30	2.28	2.33
10	8.18	7.95	7.94	7.96	6.88	6.03	6.01	6.04	5.48	3.92	3.90	3.94	6.20	4.45	4.42	4.47	4.35	2.76	2.73	2.78
11	8.21	7.98	7.97	7.99	6.80	6.07	6.06	6.08	6.17	4.60	4.59	4.62	5.34	3.97	3.94	4.00	4.20	2.83	2.80	2.85
12	8.26	7.99	7.98	8.00	6.79	6.09	6.07	6.10	6.69	5.20	5.18	5.21	4.41	3.43	3.40	3.45	3.54	2.51	2.49	2.54
13	7.86	7.99	7.98	8.00	5.66	6.07	6.06	6.08	5.32	5.67	5.65	5.69	2.30	2.83	2.80	2.85	0.68	1.85	1.82	1.88
14	7.92	7.98	7.97	7.99	5.66	6.03	6.01	6.04	5.27	6.01	5.99	6.03	1.44	2.19	2.16	2.22	-0.32	0.94	0.91	0.97
15	7.90	7.96	7.95	7.97	5.48	5.96	5.94	5.97	5.17	6.19	6.17	6.21	0.54	1.54	1.51	1.57	-1.16	-0.08	-0.12	-0.05
16	7.93	7.93	7.92	7.94	5.61	5.86	5.84	5.87	5.38	6.19	6.17	6.21	0.19	0.89	0.86	0.93	-1.38	-1.02	-1.06	-0.98
17	7.76	7.89	7.88	7.90	5.44	5.73	5.72	5.75	5.28	5.98	5.96	6.00	-0.27	0.27	0.24	0.31	-1.54	-1.69	-1.73	-1.65
18	7.85	7.84	7.83	7.85	5.60	5.59	5.57	5.60	5.35	5.55	5.53	5.57	-0.48	-0.30	-0.33	-0.26	-1.42	-1.93	-1.96	-1.89
19	7.84	7.79	7.78	7.80	5.49	5.42	5.40	5.43	5.05	4.87	4.84	4.90	-0.82	-0.81	-0.84	-0.76	-1.31	-1.52	-1.56	-1.48
20	7.85	7.73	7.71	7.75	5.55	5.22	5.20	5.25	4.80	3.92	3.88	3.95	-0.74	-1.24	-1.27	-1.17	-0.79	-0.06	-0.12	0.00

Figure A2. Mean trajectories for each latent group alongside individual trajectories (1% sample)

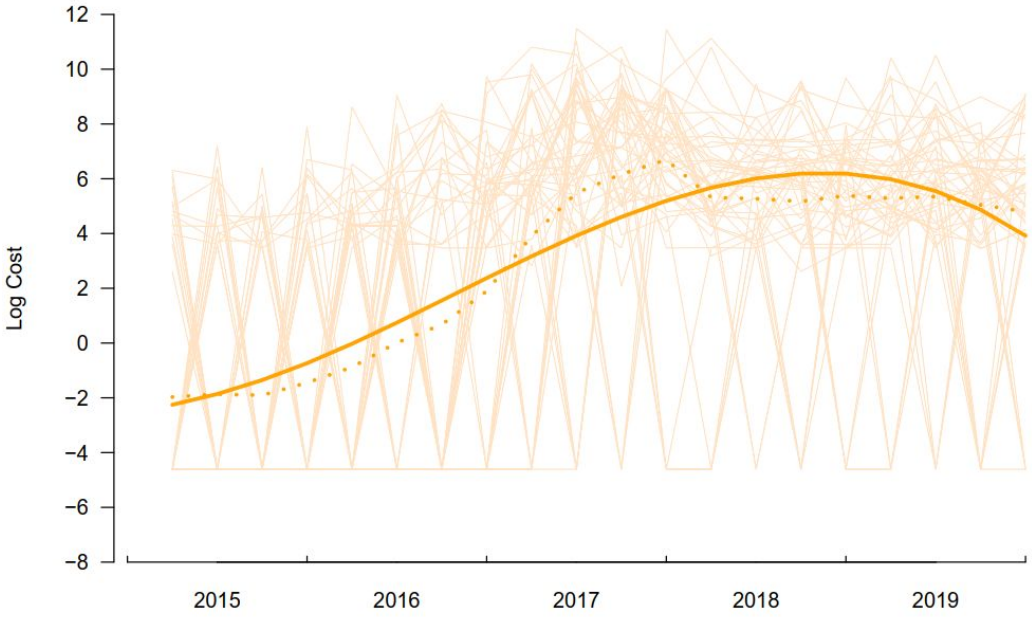
Group 1: Persistent very-high-cost



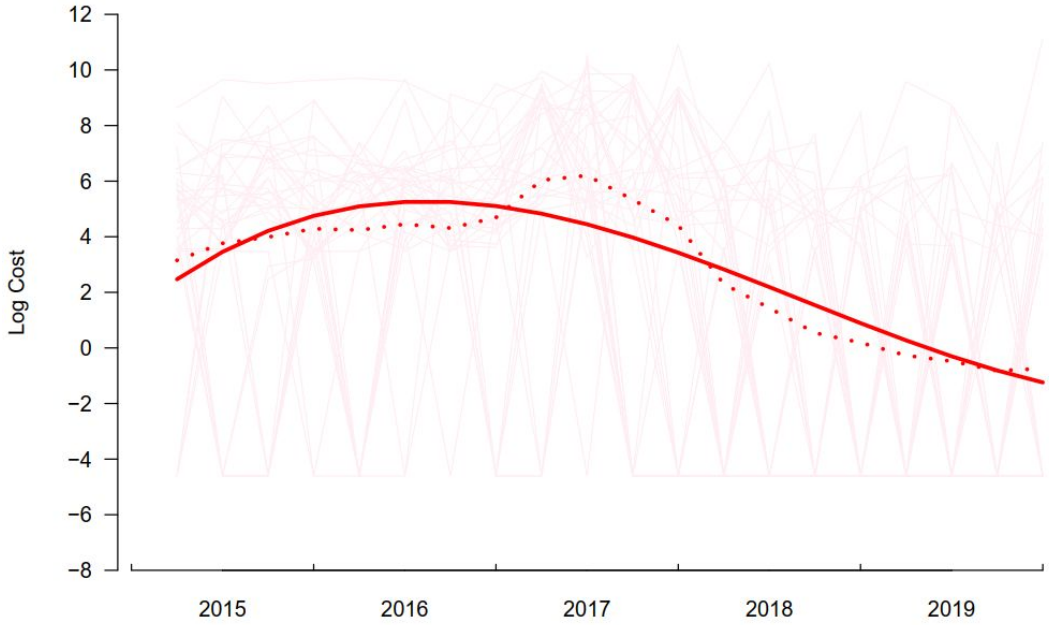
Group 2: Persistent high-cost



Group 3: Rising cost



Group 4: Declining cost



Group 5: Cost spike

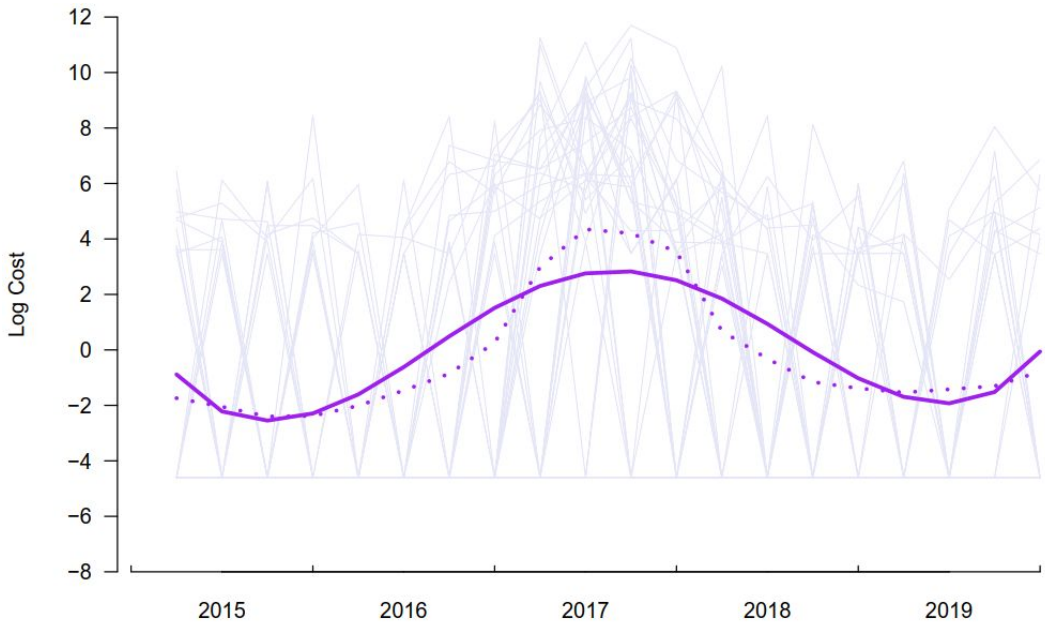
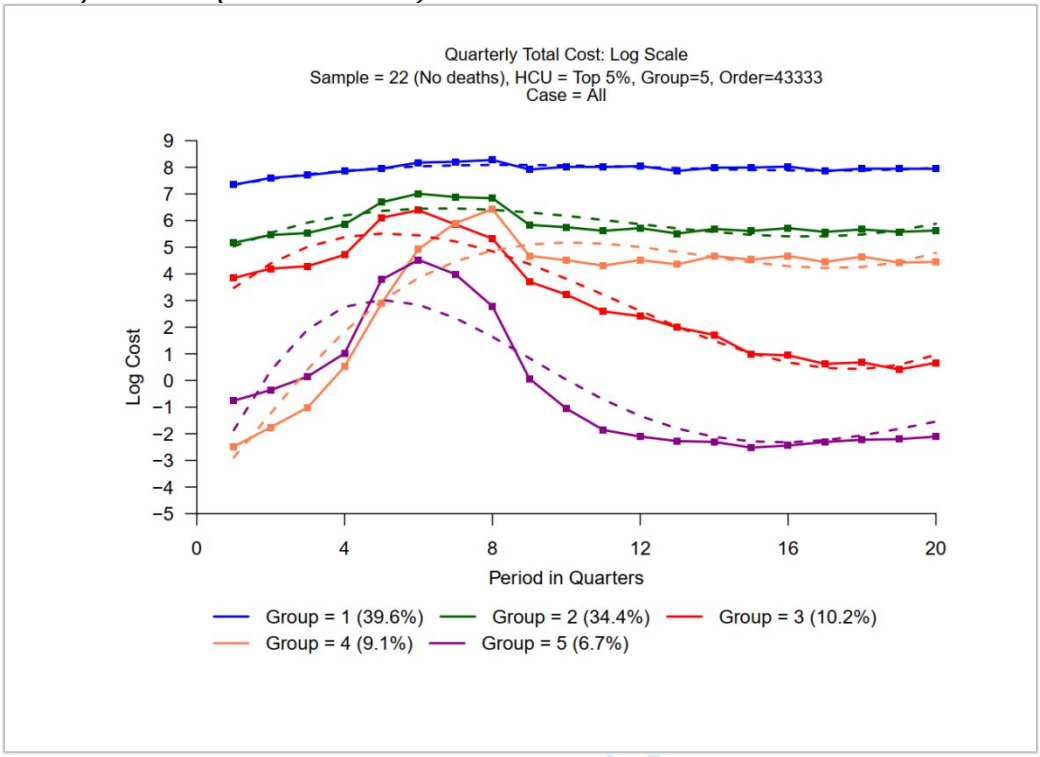


Table A3. Parameters for five-group trajectory model

Group	Parameter	Estimate	SE	t-value	pvalue
Cost spike	Intercept	2.1234	0.0414	51.2940	0.0000
Cost spike	Linear	-4.0860	0.0258	-158.1330	0.0000
Cost spike	Quadratic	0.9875	0.0048	205.4800	0.0000
Cost spike	Cubic	-0.0751	0.0003	-221.7470	0.0000
Cost spike	Quartic	0.0018	0.0000	222.7400	0.0000
Rising cost	Intercept	-3.0978	0.0258	-120.2160	0.0000
Rising cost	Linear	0.3070	0.0106	29.0050	0.0000
Rising cost	Quadratic	0.0768	0.0012	65.9070	0.0000
Rising cost	Cubic	-0.0037	0.0000	-102.8930	0.0000
Declining cost	Intercept	1.2173	0.0329	37.0040	0.0000
Declining cost	Linear	1.3766	0.0129	106.9220	0.0000
Declining cost	Quadratic	-0.1352	0.0014	-94.6240	0.0000
Declining cost	Cubic	0.0030	0.0000	66.4530	0.0000
Persistent high-cost	Intercept	3.6075	0.0166	216.9270	0.0000
Persistent high-cost	Linear	0.4412	0.0055	80.1070	0.0000
Persistent high-cost	Quadratic	-0.0218	0.0006	-36.9620	0.0000
Persistent high-cost	Cubic	0.0002	0.0000	10.2930	0.0000
Persistent very-high-cost	Intercept	6.9499	0.0112	620.3540	0.0000
Persistent very-high-cost	Linear	0.1873	0.0042	44.0910	0.0000
Persistent very-high-cost	Quadratic	-0.0095	0.0005	-20.5020	0.0000
Persistent very-high-cost	Cubic	0.0001	0.0000	7.3060	0.0000

Figure A3. Five-group trajectory model of HNHC patients based on alternative HNHC years (Sensitivity analysis 1)

HNHC year: 2016 (base case: 2017)



HNHC year: 2018 (base case: 2017)

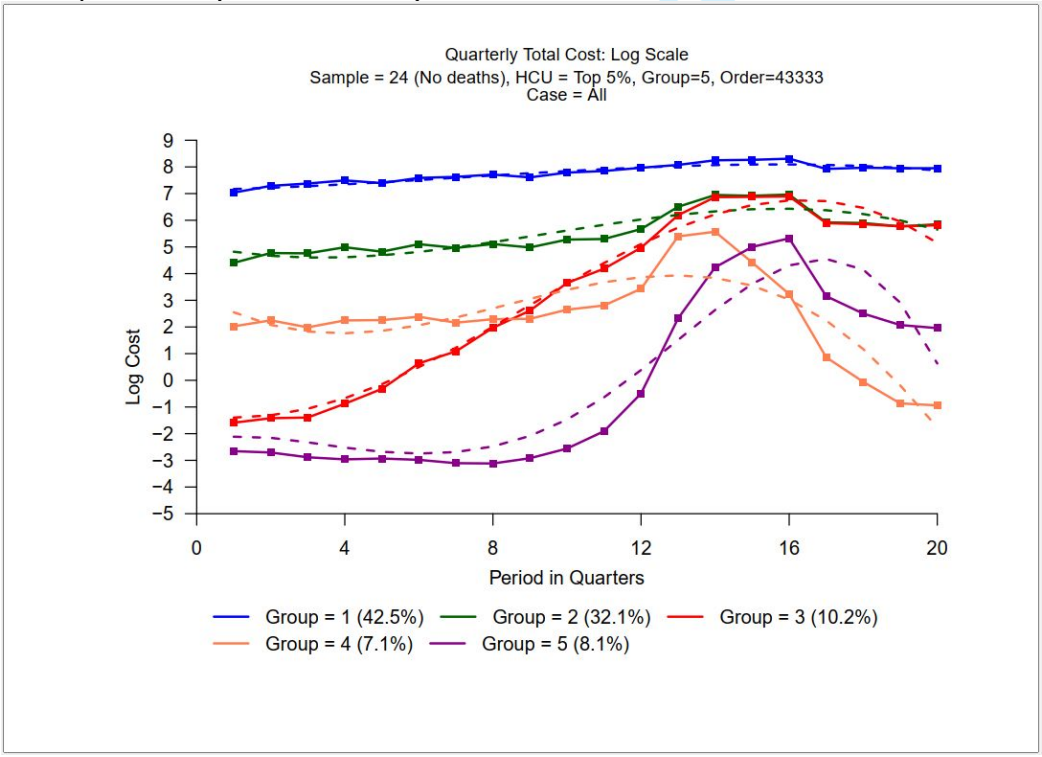
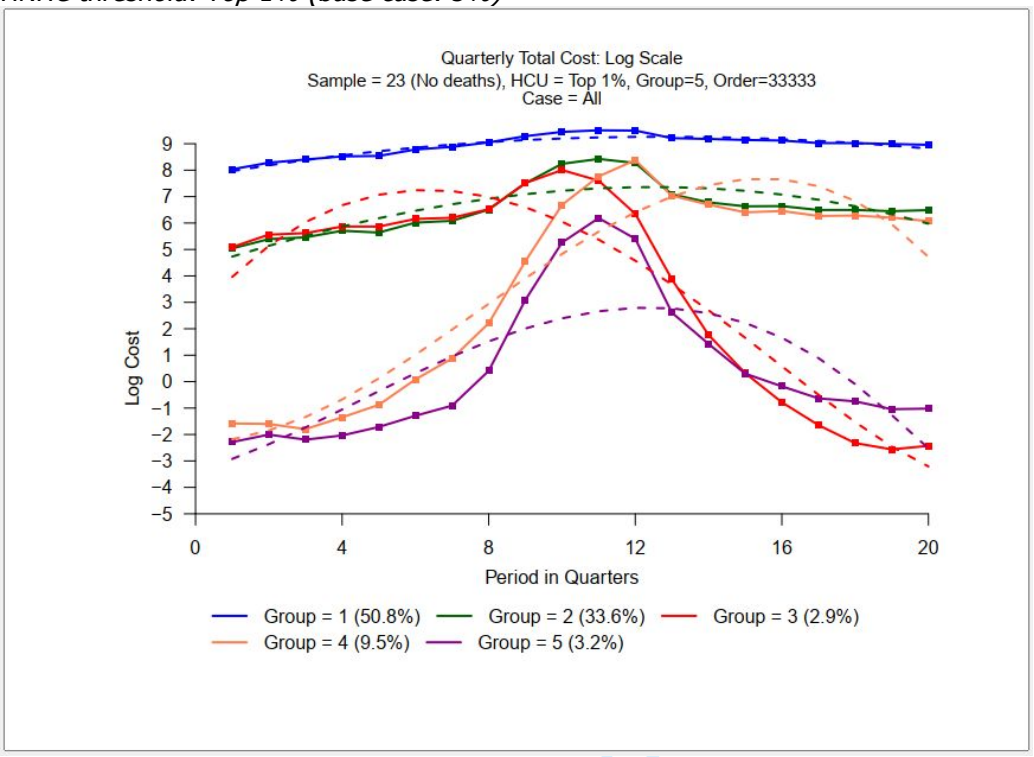


Figure A4. Five-group trajectory model of HNHC patients based on alternative HNHC thresholds (Sensitivity analysis 2)

HNHC threshold: Top 1% (base case: 5%)



HNHC threshold: Top 10% (base case: 5%)

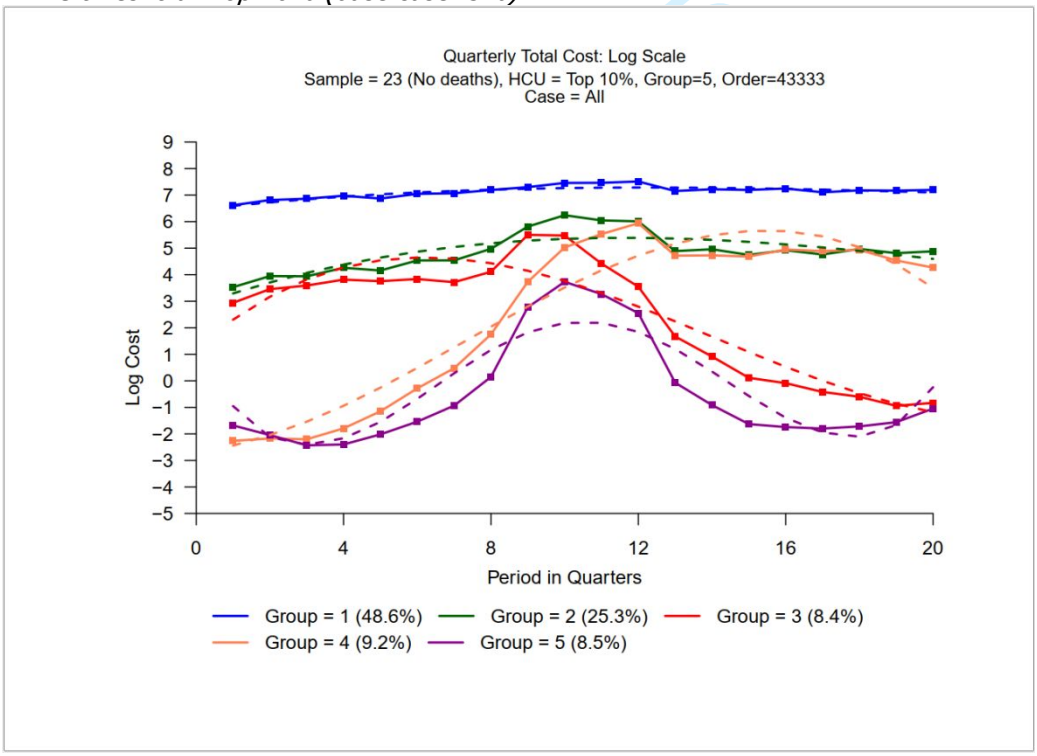


Table A4. Demographic and clinical characteristics (proportion) by trajectory group

	Persistently very-high-cost	Persistently high-cost	Rising cost	Declining cost	Cost spike
Age Group					
0-44	20.0%	26.0%	44.0%	53.0%	65.0%
45-64	31.0%	34.0%	36.0%	28.0%	26.0%
65-74	20.0%	24.0%	14.0%	11.0%	6.0%
≥75	30.0%	16.0%	6.2%	7.8%	2.1%
Sex					
Male	44.0%	44.0%	51.0%	38.0%	48.0%
Female	56.0%	56.0%	49.0%	62.0%	52.0%
Income Quintile					
1st	28.0%	20.0%	17.0%	21.0%	17.0%
2nd	21.0%	19.0%	16.0%	20.0%	17.0%
3rd	19.0%	19.0%	16.0%	19.0%	16.0%
4th	17.0%	20.0%	16.0%	19.0%	16.0%
5th	14.0%	19.0%	15.0%	17.0%	15.0%
Missing	1.5%	2.4%	21.0%	3.4%	19.3%
Geographic Region					
Metropolitan	56.0%	52.0%	43.0%	51.0%	42.0%
Non-metropolitan (hub hospital)	37.0%	38.0%	30.0%	37.0%	30.0%
Non-metropolitan (small/no hospital)	6.5%	7.8%	7.2%	8.7%	8.4%
Remote	0.2%	0.5%	0.5%	0.6%	0.8%
Missing	0.4%	1.3%	20.0%	2.1%	18.0%
Comorbidities (Elixhauser)					
0	27.0%	40.0%	42.0%	61.0%	68.0%
1	19.0%	28.0%	28.0%	20.0%	20.0%
2	17.0%	16.0%	16.0%	9.4%	7.9%
3	13.0%	8.1%	7.6%	4.7%	2.8%
≥4	24.0%	6.8%	6.8%	5.0%	1.6%

Table A5. Factors associated with group membership (adjusted odds ratio and 95% confidence interval) from multivariate multinomial logistic regression

	Persistently very-high-cost	Persistently high-cost	Rising cost	Declining cost	Cost spike
Age (per 10 years)	*Ref*	0.87 (0.87, 0.88)*	0.69 (0.68, 0.69)*	0.69 (0.68, 0.70)*	0.59 (0.58, 0.60)*
Male (ref: female)		1.10 (1.08, 1.13)*	1.70 (1.64, 1.76)*	1.07 (1.03, 1.11)*	1.89 (1.81, 1.97)*
Rural region (ref: metropolitan)		1.16 (1.13, 1.18)*	1.16 (1.13, 1.20)*	1.23 (1.18, 1.28)*	1.28 (1.23, 1.34)*
Lowest neighborhood income quintile		0.72 (0.70, 0.74)*	0.78 (0.75, 0.81)*	0.78 (0.75, 0.81)*	0.77 (0.74, 0.81)*
Comorbidities (count; ref=0)					
One		1.34 (1.29, 1.39)*	1.37 (1.29, 1.46)*	0.63 (0.59, 0.68)*	0.66 (0.59, 0.74)*
Two		1.18 (1.11, 1.24)*	1.09 (0.99, 1.21)	0.40 (0.36, 0.45)*	0.36 (0.30, 0.45)*
Three		0.97 (0.90, 1.04)	0.84 (0.73, 0.97)*	0.29 (0.25, 0.34)*	0.20 (0.15, 0.27)*
Four		0.69 (0.62, 0.77)*	0.59 (0.48, 0.72)*	0.22 (0.17, 0.28)*	0.12 (0.07, 0.19)*
Comorbidities					
Congestive Heart Failure		0.83 (0.79, 0.88)*	1.30 (1.19, 1.43)*	1.01 (0.89, 1.14)	1.05 (0.85, 1.28)
Chronic Pulmonary Disease		0.51 (0.48, 0.53)*	0.41 (0.37, 0.45)*	0.67 (0.60, 0.75)*	0.36 (0.30, 0.44)*
Diabetes		0.65 (0.63, 0.68)*	0.40 (0.37, 0.43)*	0.56 (0.51, 0.62)*	0.31 (0.26, 0.36)*
Hypothyroidism		0.89 (0.79, 1.01)	0.89 (0.71, 1.12)	1.28 (1.00, 1.62)*	0.84 (0.54, 1.28)
Renal Failure		0.49 (0.46, 0.51)*	0.40 (0.36, 0.45)*	0.62 (0.55, 0.70)*	0.27 (0.21, 0.36)*
Liver Disease		0.77 (0.71, 0.84)*	1.03 (0.92, 1.17)	0.93 (0.80, 1.08)	0.98 (0.80, 1.21)
Peptic Ulcer Disease		0.87 (0.79, 0.96)*	0.80 (0.68, 0.96)*	0.89 (0.71, 1.10)	0.78 (0.56, 1.07)
AIDS/HIV		0.63 (0.48, 0.84)*	0.43 (0.26, 0.71)*	0.55 (0.30, 1.01)	0.38 (0.15, 0.98)*
Lymphoma		1.29 (1.14, 1.46)*	1.54 (1.28, 1.87)*	1.00 (0.74, 1.35)	0.77 (0.51, 1.18)
Metastatic Cancer		1.13 (1.04, 1.22)*	1.57 (1.40, 1.76)*	1.36 (1.15, 1.61)*	1.35 (1.07, 1.70)*
Cardiac Arrhythmia		1.01 (0.97, 1.05)	1.00 (0.93, 1.08)	1.23 (1.12, 1.34)*	1.05 (0.91, 1.22)
Solid Tumor without Metastasis		1.47 (1.40, 1.53)*	2.12 (1.96, 2.28)*	1.42 (1.28, 1.57)*	1.72 (1.48, 1.98)*
Rheumatoid Arthritis		0.30 (0.27, 0.33)*	0.19 (0.15, 0.24)*	0.32 (0.25, 0.41)*	0.14 (0.09, 0.21)*

Coagulopathy		0.80 (0.73, 0.88)*	0.87 (0.75, 1.01)	1.14 (0.96, 1.36)	0.99 (0.77, 1.28)
Obesity		1.03 (0.94, 1.12)	0.61 (0.51, 0.72)*	1.67 (1.45, 1.93)*	0.93 (0.74, 1.17)
Weight Loss		0.62 (0.57, 0.67)*	0.80 (0.69, 0.92)*	0.85 (0.72, 1.02)	0.86 (0.67, 1.11)
Fluid/Electrolyte Disorders		0.72 (0.69, 0.75)*	0.78 (0.72, 0.84)*	0.94 (0.86, 1.03)	0.96 (0.83, 1.11)
Blood Loss Anemia		0.82 (0.72, 0.93)*	1.01 (0.81, 1.24)	1.05 (0.81, 1.36)	1.41 (1.00, 1.98)*
Deficiency Anemia		0.79 (0.74, 0.84)*	0.81 (0.72, 0.92)*	0.97 (0.84, 1.11)	0.86 (0.70, 1.06)
Alcohol Abuse		1.47 (1.39, 1.56)*	1.69 (1.54, 1.84)*	2.21 (1.99, 2.45)*	2.49 (2.16, 2.88)*
Drug Abuse		0.47 (0.44, 0.49)*	0.48 (0.44, 0.52)*	0.69 (0.63, 0.76)*	0.49 (0.43, 0.57)*
Valvular Disease		1.16 (1.08, 1.25)*	1.11 (0.97, 1.26)	1.14 (0.96, 1.36)	1.11 (0.84, 1.46)
Mental		0.47 (0.45, 0.49)*	0.57 (0.53, 0.61)*	0.54 (0.49, 0.59)*	0.54 (0.47, 0.61)*
Pulmonary Circulation Disorders		0.89 (0.82, 0.96)*	1.23 (1.08, 1.39)*	0.94 (0.79, 1.12)	1.26 (1.00, 1.58)*
Hypertension		1.15 (1.11, 1.20)*	1.36 (1.27, 1.46)*	1.23 (1.12, 1.36)*	1.27 (1.11, 1.47)*
Paralysis		0.82 (0.75, 0.89)*	1.58 (1.40, 1.79)*	0.98 (0.81, 1.19)	0.94 (0.72, 1.24)
Other Neurological Disorders		0.49 (0.46, 0.52)*	0.51 (0.46, 0.56)*	0.55 (0.49, 0.63)*	0.31 (0.25, 0.37)*

Figure A5. Forest plot of factors associated with group membership, relative to the 'very-high-cost' trajectory group, from multinomial logistic regression with *forward variable selection* (adjusted Odds Ratios, 95% CI)