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Individual Heterogeneity in the Probability of Hospitalization, Skilled Nursing Facility Admission, and Mortality

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Abstract

Background: Multimorbidity is common in adults aged 65 and older and is associated with health care utilization and mortality, but most methods ignore the interrelationship among concurrent outcome nor provide person-specific probabilities.

Method: A longitudinal cohort of 5300 older Americans from the 2011–2015 rounds of the National Health and Aging Study was linked to Center for Medicare and Medicaid Services claims. Odds ratios for 15 chronic conditions adjusted for sociodemographic factors were estimated using a joint model of hospitalization, skilled nursing facility (SNF) admission, and mortality. Additionally, we estimated the person-specific probability of an outcome while currently at risk for other outcomes for different chronic disease combinations demonstrating the heterogeneity across persons with identical chronic conditions.

Results: During the 4-year follow-up period, 2867 (54.1%) individuals were hospitalized, 1029 (19.4%) were admitted to a SNF, and 1237 (23.3%) died. Chronic kidney disease, dementia, heart failure, and chronic obstructive pulmonary disease had significant increased odds for all 3 outcomes. By incorporating a person-specific random intercept, there was considerable range of person-specific probabilities for individuals with hypertension, diabetes, and depression with dementia, (hospitalization: 0.14–0.61; SNF admission: 0.04–0.28) and without dementia (hospitalization: 0.07–0.44; SNF admission: 0.02–0.15). Such heterogeneity was found among individuals with heart failure, ischemic heart disease, chronic kidney disease, hypertension, hyperlipidemia, and osteoarthritis with and without Medicare.

Conclusions: This approach of joint modeling of interrelated concurrent health care and mortality outcomes not only provides a cohort-level odds and probabilities but addresses the heterogeneity among otherwise similarly characterized persons identifying those with above-average probability of poor outcomes.

Keywords: Health care utilization, Joint model, Multimorbidity, Personalized risk

Increased life expectancy has resulted in over 60% of older adults having 2 or more chronic conditions, that is, multimorbidity, to manage as they age (1–3). Multimorbidity is associated with increased health care needs, including hospitalizations and skilled nursing facility (SNF) admissions, mortality, greater financial burden for families, caregiver stress, and declines in functional abilities and quality of life (4).

Strategies for addressing the rising problem of multimorbidity require up-to-date and accurate identification of the contribution of individual chronic conditions to health care outcomes at the population and person level. Observational studies examining the impact of chronic conditions on health outcomes have typically focused on single outcomes and emphasized measures of relative risk, that are less informative then absolute measures. Patient-level management strategies would benefit knowing whether the person was at above- or below-average probability of health care utilization of death, while cohort-level strategies, such as health care system coverage, benefit from estimates of cohort probability of health outcomes. This contribution to Research Practice presents analytic methods that address the heterogeneity arising from

possible combinations of sociodemographic characteristics and chronic conditions by demonstrating the estimation of person-specific probability. In addition, even though many outcomes, such as hospitalizations, SNF stays, and mortality are interrelated, chronic conditions or sociodemographic characteristics may have differing risks for each.

We are motivated by the common scenario that community-dwelling older adults may be discharged from a hospital to a SNF, rather than home, due to hospital procedures, insurance type, their prognosis, or the availability of a caregiver at home (4). Each chronic conditions may have unique associations with hospitalization (5). In-hospital mortality could have different risk factors than deaths occurring in a SNF setting or the community. These person-level intercorrelations between the occurrence of these 3 outcomes should be incorporated into analytic models.

We expanded previously published methods for jointly modeling multiple outcomes, where each person's shared influences on concurrent outcomes can be captured by using a random intercept term (6–8). Based on the estimates from the joint model, the typical concurrent risk (TCR) of each outcome (ie, probability) can be estimated at the cohort level, providing a method for identifying average longitudinal effects of risk factors useful for health care system policies. In contrast, a person-specific effect reflects the probability of each outcome (ie personalized concurrent risk [PCR]). Chronic conditions and sociodemographic risk factors rarely capture the extent of the heterogeneity of a cohort; thus, methods to identify persons at above- (or below-) average risk may assist health care systems more than the average (TCR) estimate. We expanded these joint models to address truncation of measurement due to death and the interdependence of outcomes at the person level, while maintaining the Type I error (9).

The growing burden of multimorbidity was addressed by a U.S. Department of Health and Human Services initiative on multimorbidity that noted the importance of research studies that (i) "Develop tools to identify and target population subgroups of individuals with multiple chronic conditions who are at high risk for poor health outcomes" and (ii) "Improve knowledge about patient trajectories temporally in relation to changes is health status, functional status and health services use" (10). The current study addresses these goals to better understand the associations of 15 common chronic conditions with 3 interrelated outcomes (hospitalization, SNF admission, and mortality) simultaneously over 4 years, which has not been previously demonstrated in the literature. In addition, we present 2 examples for different combinations of chronic conditions and sociodemographic factors for each outcome's PCR and TCR.

Method

Sample

This study included participants in the National Health and Aging Trends Study (NHATS) (11,12). NHATS is an ongoing longitudinal study, of a U.S. nationally representative sample. Participants are interviewed at yearly intervals to obtain information on functioning, impairments, symptoms, and social environment. Five annual waves of data from the NHATS were merged with Center for Medicare and Medicaid Services (CMS) claims data from 2011 to 2015. The claims linked to the NHATS contained information on chronic conditions and procedures, in addition to information on hospitalizations and SNF admissions.

This study protocol was approved by the Johns Hopkins University Institutional Review Board (IRB) and the Yale IRB (HIC# 1510016585).

We included NHATS respondents who were Medicare fee-for service beneficiaries. Medicare managed care enrollees were excluded because their claims data were unavailable. We limited the study to those 67 years and older at baseline, or who reached age 67 during the follow-up period, to ensure adequate look-back period for the chronic condition ascertainment period described below. Participants who had missing data on education or race were also excluded from the analysis (*n* = 79). The final sample consisted of 5300 community-dwelling beneficiaries who completed an initial interview and had at least 1 year of follow-up data. Sociodemographic information included age in years, sex, and race/ethnicity (non-Hispanic Whites vs others), education (less than high school vs high school or more), and Medicaid eligibility status. However, disability in activities of daily living were multiply correlated with the set of chronic conditions, thus, were not included in the models.

Chronic Conditions

Chronic Condition Data Warehouse (CCDW) data from the years 2011 to 2015 were obtained for study participants. The CCDW is a research database containing fee-for-service Medicare and Medicaid claims. Institutional and noninstitutional claims information on diagnoses and treatment are used to create indicators for 27 predefined chronic conditions.

We examined a subset of 15 conditions in this study (see Table 1) based on a list of 20 selected chronic conditions, suggested by a working group on defining and measuring chronic conditions excluding autism, cancer, hepatitis, HIV, schizophrenia, and substance abuse (13). Aside from cancer, these either did not occur in our data or there were fewer than 10 observations; thus, we were not able to include them. Cancer has many specific ICD codes and could be recent or in-remission, resulting in a heterogenous category limiting the generality and clinical meaning of associations. For this study, the "dementia" condition consisted of Alzheimer's and related dementias (ADRD).

The algorithms for each condition can be accessed on the CCDW website (https://www2.ccwdata.org/web/guest/home). Briefly, chronic conditions from the CCDW are identified based on ICD-9 diagnosis and Current Procedural Terminology (fourth edition), and Healthcare Common Procedure Coding System (Level II) procedure codes, for specific types of claims (eg, inpatient, SNF) within a specified reference period (1–3 years).

For each calendar year, data covering 2 time periods are available, specifically January to June and July to December for 2011–2015. In addition, CCDW data encoding for the chronic conditions were available for the years preceding 2011 (1999–2010) for those who had been enrolled in fee-for-service Medicare. Given the chronic nature of these conditions, information was carried forward from 1999 to 2010 to the initial interview (2011) included in the analysis. These conditions (see Table 1) were considered present if the person met the clinical criteria for a condition (ie using claims data) without necessarily meeting coverage criteria for the previous calendar years. Using similar clinical criteria, chronic conditions occurring during this study follow-up were also carried forward in subsequent follow-up periods. However, for surviving participants, we required at least 11 months of fee-for-service coverage during a calendar year to be included in that year. This allowed for a 1-month

Table 1. Baseline Characteristics and the Prevalence and Incidence of 15 Chronic Conditions of Medicare Fee-for-Service Beneficiaries 67 Years and Older Participating in the National Health and Aging Study (2011–2015) Linked to the Chronic Condition Data Warehouse

	Total *N* = 5300	
Characteristic	*n* (%)	
Age: Mean (±*SD*)	78.0 (7.8)	Range: 67–106
67–74	2041 (38.5)	
75–84	2093 (39.5)	
85 and older	1166 (22.0)	
Female	3049 (57.5)	
White, non-Hispanic	3753 (70.8)	
≥High school	3905 (73.7)	
Medicaid eligible	835 (15.8)	

Chronic Conditions	Baseline Prevalence, *n* (%)	Incidence/ 1000 person-years
Arthritis[a]	2769 (52.2)	64.1
Asthma	606 (11.4)	8.7
Atrial fibrillation	718 (13.6)	20.5
Chronic kidney disease	1037 (19.6)	51.8
COPD	1224 (23.1)	28.3
Dementia[b]	662 (12.5)	32.0
Depression	1195 (22.6)	29.2
Diabetes	1844 (34.8)	24.6
Heart failure	1464 (27.6)	38.0
Hyperlipidemia	3803 (71.8)	84.9
Hypertension	4130 (77.9)	95.7
Ischemic heart disease	2566 (48.4)	47.7
Myocardial infarction	231 (4.4)	5.7
Osteoporosis	1136 (21.4)	17.9
Stroke or TIA	804 (15.2)	18.3
Total conditions		
None	570 (10.8)	
1	300 (5.7)	
2–3	1134 (21.4)	
4–5	1304 (24.6)	
≥6	1992 (37.6)	

Notes: COPD = chronic obstructive pulmonary disease; TIA = transient ischemic attack.

[a]Rheumatoid or osteoarthritis. [b]Alzheimer's and other related dementias.

gap in Medicare coverage for those beneficiaries who may switch from a managed care program.

Outcomes

Any hospitalization and any SNF admission in each 6-month interval over follow-up period of 2011–2015, both identified by claims submitted for that time period, were concurrent outcomes. Each participant could have multiple hospitalizations and/or SNF admissions. Vital status information came from the master beneficiary summary file.

Statistical Analysis

Sociodemographic characteristics and the prevalences of the 15 chronic conditions at baseline were summarized using frequencies. The incidence of newly developed chronic conditions over the 4-year follow-up was calculated as rates per 1000 person-years. The Kendall Tau-*b* statistic was used to estimate the correlation among the 3 outcomes.

We used a previously published shared random intercept joint modeling approach to estimate the associations for all chronic conditions with the concurrent longitudinal binary outcomes (6–8) (https://crcoder.phs.wakehealth.edu). We extended the joint model to incorporate a logit link for the 3 binary outcomes, any hospitalization, any SNF admission and death, during each 6-month time interval over the follow-up period of 2011–2015, via a pooled logistic regression model. Adjusted odds ratios (aORs) and 95% confidence intervals (CIs) for the fixed (ie, age, sex, race/ethnicity, education) and time-varying effects (ie, Medicaid eligibility and each chronic condition) were estimated for each outcome. The person-specific random intercept reflects the shared information between the 3 outcomes for each subject (7). SAS v9.4 (SAS Institute Inc, Cary, NC) was used for all analyses, with *p* <.05 (2-sided) interpreted as statistically significant.

To translate the findings from relative measure of aORs into an absolute measure of probability to identify individuals with above- or below-average probability of each outcome, we present 2 examples. The PCR is the person-specific probability of an outcome within a defined interval of time, while currently at risk for another nonmutually exclusive outcome (7). This is not to be confused with traditional prediction modeling, rather as a means of providing person-specific probability rather than relative measures. Further, we estimate the cohort-level average probability (TCR) by taking the inverse logit link function of the estimates while setting the random intercept to zero (7). In the first example, a reduced joint model with age, sex, hypertension, diabetes, and depression and dementia was estimated and the PCR and TCR were plotted for females, aged 85, with hypertension, diabetes, and depression with and without dementia. In the second example, a reduced joint model with age, sex, heart failure, ischemic heart disease, chronic kidney disease, hypertension, hyperlipidemia, osteoarthritis, and an indicator for Medicaid coverage were the risk factors. Plots for females aged 85, with these conditions, were then generated by Medicaid coverage.

Ethics Statement

This study protocol was approved by the Johns Hopkins University Institutional Review Board (IRB) and the Yale IRB (HIC# 1510016585).

Results

The baseline characteristics of the 5300 individuals included in this study are presented in Table 1. The mean age was 78.0 years, over half were female (57.5%), and the majority were White and non-Hispanic (70.8%), with a high school or greater education (73.7%). Eligibility criteria for Medicaid were met for 835 (15.8%) participants.

As shown in Table 1, cardiovascular conditions were highly prevalent at baseline, including hypertension (77.9%) and hyperlipidemia (71.8%). The incidence of cardiovascular conditions over the 4 years of follow-up was considerable for hypertension with 95.7/1,000 person-years, followed by 84.9/1000 person-years and hyperlipidemia. For the 3 particularly debilitating conditions, the incidence rate for chronic kidney disease was 51.8/1000 person-years, for heart failure 38.0/1000 person-years, and for dementia

32/1000 person-years. Nearly 85% had multimorbidity at baseline with 19.8% of the participants had 2–3 chronic conditions, 24.4% had 4–5, and 40% had 6 or more conditions.

Joint Model of Hospitalization, SNF Admission, and Mortality

During the 4-year follow-up period, 1387 (26.2%) had 1, 811 (15.3%) had 2, and 669 (12.6%) had 3 or more hospitalizations, while 745 (14.1%) had 1, 214 (4.0%) had 2, and 70 (1.3%) had 3 or more SNF admissions, and 1237 (23.3%) died. The correlation between hospitalization and SNF admission was 0.45 (95% CI = 0.44–0.46) using a Kendall's tau-*b*. The correlations were smaller for hospitalization and death (Kendall's tau-*b* = 0.23, 95% CI = 0.21–0.24), and SNF admission and death (Kendall's tau-*b* = 0.15, 95% CI = 0.13–0.17).

Figure 1 displays the joint model results for the 3 outcomes. Fourteen of the 15 chronic conditions were associated with being hospitalized, with only hyperlipidemia associated with being less likely to be hospitalized. The largest aORs were seen for chronic kidney disease (aOR = 1.50, 95% CI = 1.38–1.64), heart failure (aOR = 1.44, 95% CI = 1.31–1.58), chronic obstructive pulmonary disease (aOR = 1.40, 95% CI = 1.28–1.53), and dementia (aOR = 1.36, 95% CI = 1.23–1.51).

Most of the chronic conditions associated with hospital admission were also associated with admission to a SNF, except for asthma and myocardial infarction. The largest aORs followed a different pattern for SNF admission as compared to hospital admission, with hypertension (aOR = 1.58, 95% CI = 1.20–2.09), followed by dementia (aOR = 1.55, 95% CI = 1.33–1.80), depression (aOR = 1.49, 95% CI = 1.30–1.72), chronic kidney disease (aOR = 1.48, 95% CI = 0.128–1.70), and heart failure (aOR = 1.43, 95% CI = 1.23–1.66).

Finally, 7 of the 15 conditions were associated with higher odds of mortality, with the largest aORs for dementia (aOR = 2.24, 95% CI = 1.94–2.59), followed by chronic kidney disease (aOR = 1.77, 95% CI = 1.54), while arthritis (aOR = 0.82, 95% CI = 0.71–0.96) and hyperlipidemia (aOR = 0.63, 95% CI = 0.53–0.75) were associated with lower odds of mortality.

Interpreting Personalized and Typical Concurrent Risks

Figure 2 plots the PCR and TCR for hospitalization (top), SNF admission (middle), and mortality (bottom) for 18 women, 85 years old, with hypertension, diabetes, and depression. The solid circles and solid horizontal line reflect those who did not have dementia (*n* = 9), while the open squares and dashed lines reflect those with dementia (*n* = 9). These persons are presented from the lowest person-specific random intercept to the highest among this group by dementia status; thus, the woman with the lowest random intercept is the furthest left in all panels and the woman with the highest intercept is the furthest right in all panels.

First, the dashed and solid horizontal lines in each panel reflect the TCRs that were calculated using the model coefficients for hypertension, diabetes, depression, and setting age to 85 years. The TCR reflects the cohort-level average probability of experiencing the outcome. Comparing the solid lines (no dementia) to the dashed lines (dementia), we see that the TCR (average probability) is higher for the hospitalization, SNF admission, and mortality for those with dementia.
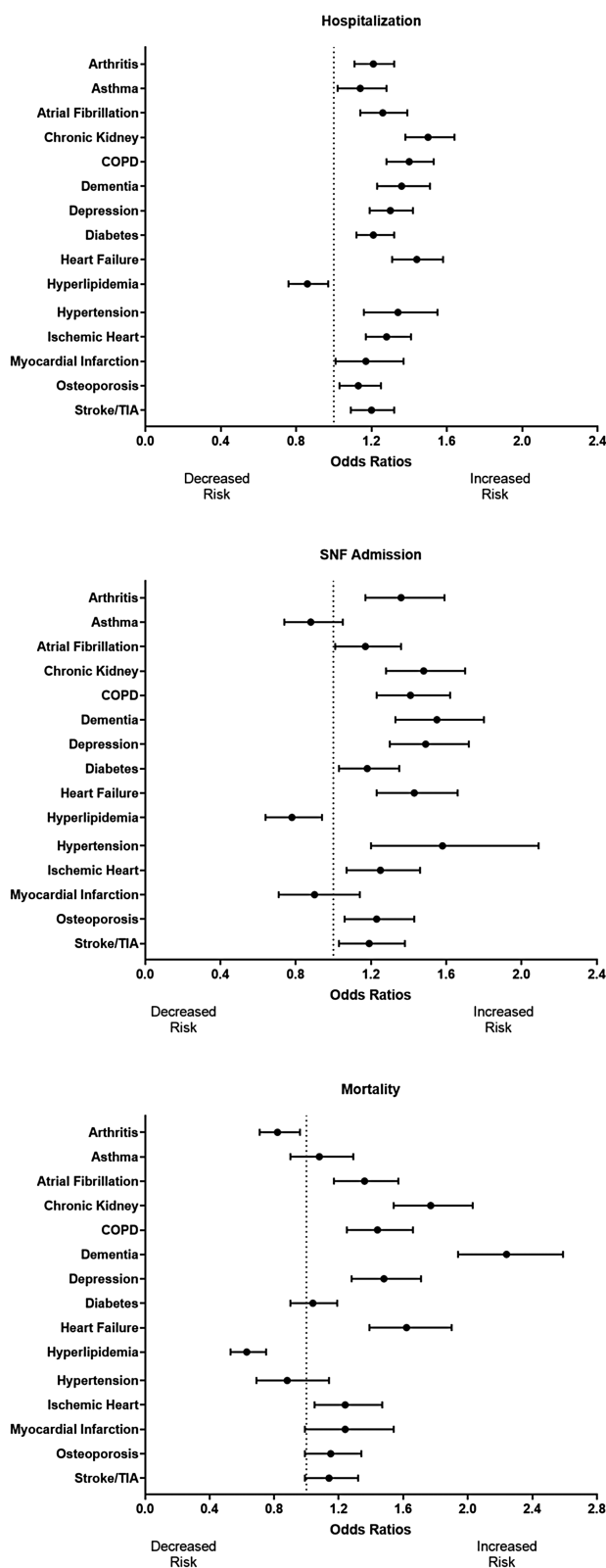

Figure 1. Adjusted odds ratios for chronic conditions from a longitudinal joint model of hospitalization, skilled nursing facility (SNF) admission, and mortality adjusted for age, sex, race/ethnicity, education, and medicaid eligibility. COPD = chronic obstructive pulmonary disease; TIA = transient ischemic attack. C-statistics were 0.84 for hospitalization, and 0.89 for SNF admission and mortality.
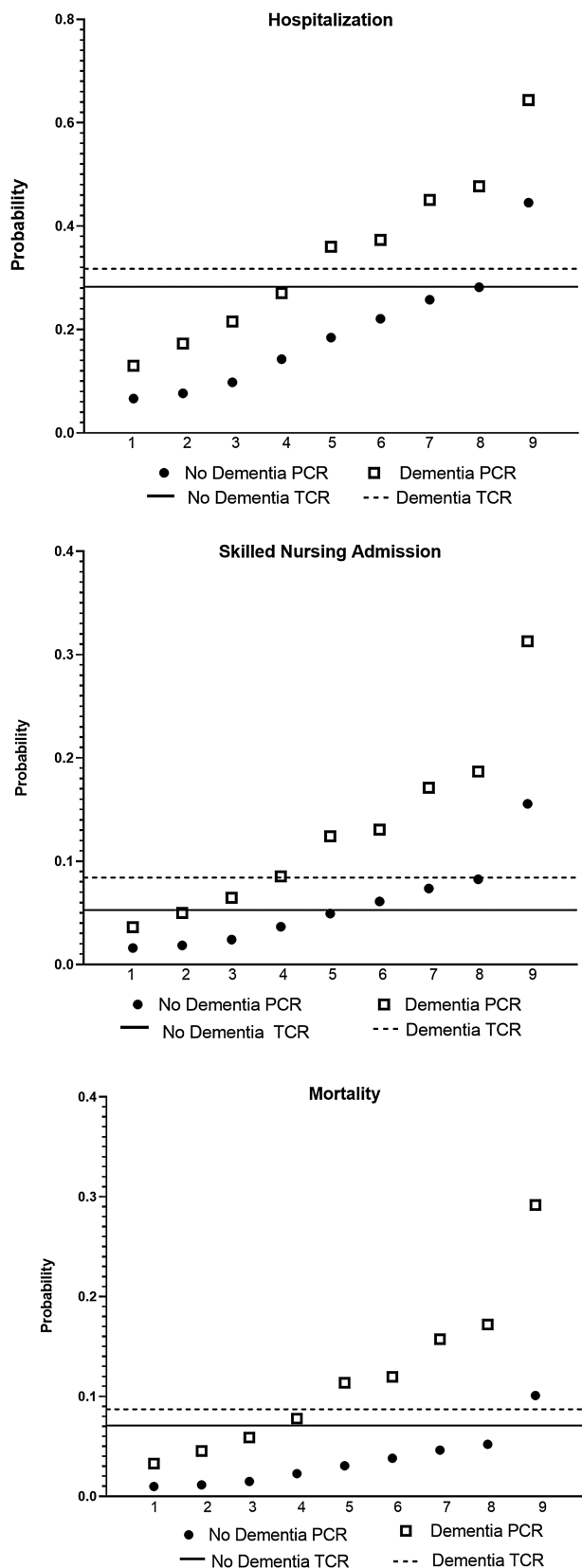
Figure 2. Personalized and typical concurrent risk for hospitalization, skilled nursing facility (SNF) admission, and death among women aged 85 years with hypertension, diabetes, and depression, with and without co-occurring dementia. The solid circles and solid horizontal line reflect those who did not have dementia (*n* = 9), while the open squares and dashed lines reflect those with dementia (*n* = 9). These persons are presented from the lowest person-specific random intercept to the highest among this group by dementia status; thus, the woman with the lowest random intercept is the furthest left in all panels and the woman with the highest intercept is the furthest right in all panels.

Next, the person-specific probabilities (PCRs) were calculated using the coefficients as described above, in addition to the random intercepts for each person. Having a negative random intercept results in a PCR below the TCR (eg, lower-than-average probability), while a random intercept >0 reflects a higher-than-average probability (PCR is greater than the TCR). The range of the PCRs displayed in Figure 2 reflects the heterogeneity in probabilities across the 3 outcomes. For example, the TCR for hospitalization is 0.28 for those without dementia, and 0.32 for those with dementia, while the PCRs range from 0.07 to 0.46 for those without dementia and from 0.13 to 0.64 for those with dementia. Similar patterns are seen for SNF admissions and death.

Figure 3 plots the PCR and TCR for hospitalization and SNF admission, for 18 women, 85 years old, with heart failure, ischemic heart disease, chronic kidney disease, hypertension, hyperlipidemia, and osteoarthritis with Medicare (*n* = 9) (solid circle and solid line) and without Medicare (*n* = 9) (open square and dashed line). These women are ordered from lowest person-specific random intercept to highest. Notably, those with Medicaid are at a higher probability for all outcomes, with considerable heterogeneity ranging from 0.14 to 0.71 for hospitalization, 0.03 to 0.33 for SNF, and 0.03 to 0.33 for mortality.

Discussion

This study used a joint model to examine the interrelationships among 15 chronic conditions and hospitalization, SNF admission, and death events occurring concurrently over a 4-year time period. The PCR is an absolute measure probability that shows the heterogeneity for each outcome for persons with the same characteristics. This identifies persons with above-average probability of an outcome potentially allowing health care services to be directed to these people. It also identifies persons with below-average probability of an outcome, which could be informative to a health care system by investigating if these people have had treatment or interventions that have reduced their probability of poor outcomes.

Chronic Conditions

The burden of multimorbidity is higher than those in prior reports, most likely due to the length of the look-back period examined for prior condition claims (1999–2010) (1–3). The prevalence estimates for these 15 conditions from a nationally representative cohort were higher than those reported in previous studies, although the most common conditions identified—arthritis, hypertension, hyperlipidemia, heart disease, and diabetes—are reflected in previous studies (1–3).

Hypertension and hyperlipidemia had the highest incidence rates based on the 2011–2015 time period, while arthritis had the third highest incidence followed by chronic kidney disease. There are few longitudinal studies that estimate incidence for all of these common conditions, especially with a well-characterized nationally representative cohort. However, the age range of participants, conditions studied, and source of information (eg, claims, self-report, primary care medical records) make it difficult to conduct comparisons with studies focused on individual conditions. Overall, these

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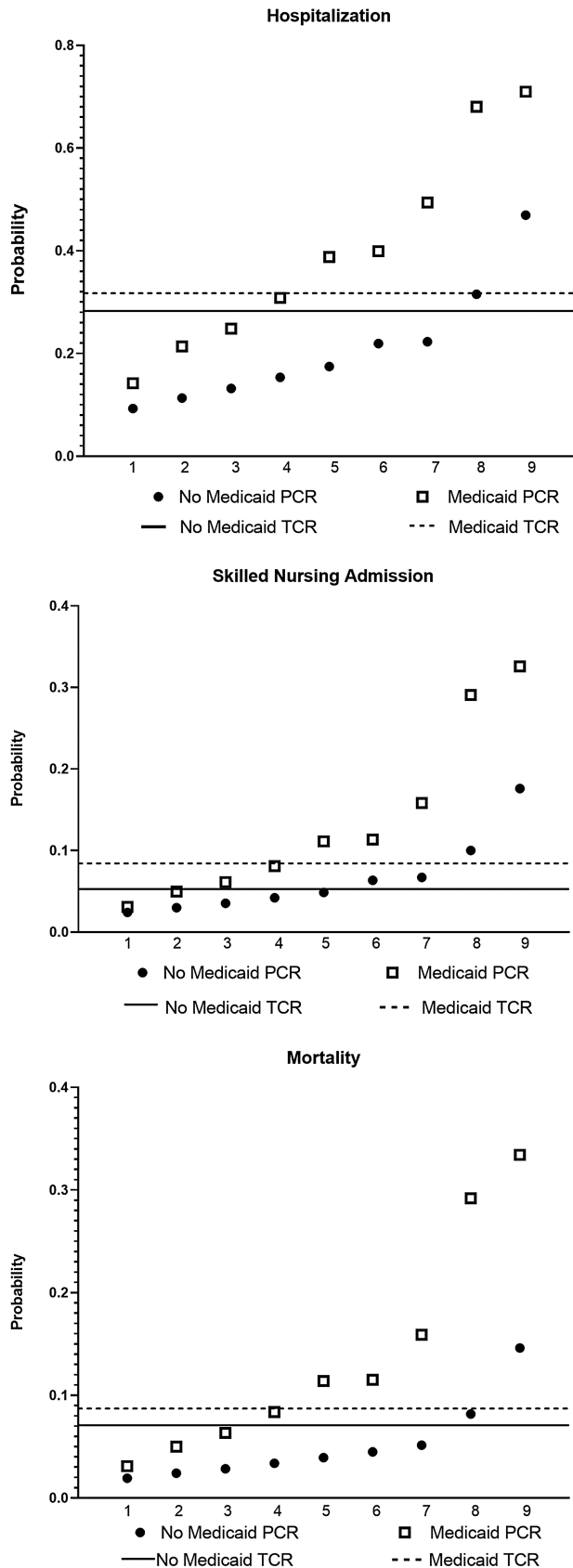
Figure 3. Personalized and typical concurrent risk for hospitalization and skilled nursing facility (SNF) admission and death among women aged 85 years with heart failure, chronic kidney disease, ischemic heart disease,

claim-based incidences of arthritis, asthma, atrial fibrillation, kidney disease depression, diabetes, hyperlipidemia, hypertension, ischemic heart disease, and stroke are higher than previous reports, on the other hand debilitating conditions including chronic obstructive pulmonary disease, dementia, heart failure, and myocardial infarction occurred less frequently (14–28).

Joint Model of Hospitalization, SNF Admission, and Mortality

We used a joint model of health care utilization and mortality to account for the correlations among the 3 outcomes. In this sample of 5300 older adults, there were 1672 different combinations of the 15 chronic conditions present at baseline, reflecting the complex patterns of comorbidity. In addition to providing estimates at the cohort level, this approach provides person-specific absolute measures of probability.

The majority of the 15 chronic conditions examined were associated with hospitalization and SNF admission. Prior research has confirmed an increase in hospitalizations, length of stay, and costs, as a function of the number of chronic conditions, but these studies were mostly cross-sectional, focus on costs, and do not capture effects of individual conditions (29–32). This study furthers our knowledge of the risk factors for hospitalization by examining individual conditions instead of a count of the number of comorbidities and new cases of disease were captured by using a longitudinal design.

Two systematic reviews of risk factors for SNF admission found that dementia or cognitive impairment was consistently the strongest factor associated with institutionalization, in agreement with our findings (33,34). Their meta-analysis of predictors of time to nursing home admission of 7 common chronic conditions found that lung disease and stroke were associated with SNF admission, while a second review article rated the level of evidence for 10 of the conditions included in this study. In addition to dementia, diabetes had a high quality of evidence (100% of studies significant association), while none of the studies on cerebrovascular disease, arteriosclerosis, and osteoporosis found significant associations with SNF admission were significant. The other conditions including heart/circulatory, stroke, hypertension, arthritis, and respiratory conditions were mixed across studies (33,34).

Although fewer conditions were associated with mortality, the largest effect estimates across outcomes were seen for mortality, documenting the impact of more debilitating conditions including dementia, heart failure, and chronic kidney disease. Tinetti et al. found high risk of death for dementia and heart failure using data from the Medicare Current Beneficiary Survey, while Schafer et al. reported that cancer, dementia, and Parkinson's disease were among the conditions with the largest risks of death (hazard ratios ≥ 1.40) (35–37).

While the TCR estimates the average cohort probability, one advantage of the joint modeling approach is the ability to identify persons at above- (or below-) average probability using the PCR. Health care systems could use these PCRs to identify patients who are more likely to experience poor outcomes and compare their treatments or therapies to those with below-average probability. These approaches may help health care systems to identify actionable improvement in care delivery through improved clinical decision support. Currently,

hypertension, hyperlipidemia, and arthritis with (open square and dashed line) and without Medicare (*n* = 9) (solid circle and solid line). These women are ordered from lowest person-specific random intercept to highest.

there are electronic health record linked, web-based clinical decision support systems implemented across multiple health care systems that have improved chronic disease care, high usage and demonstrated clinician satisfaction (38). Recent evidence from a cluster-randomized trial to algorithmically identify patients at high cardiovascular outcome risk found that staff prompted to print clinical evidence-based treatment options for lipid, blood pressure, weight, tobacco, or aspirin management and prioritized them based on potential benefit to the patient successfully lowered 10-years cardiovascular risk (39).

The example presented in Figure 3 showed that 2 women with Medicaid coverage had a very high risk for hospitalization with probabilities >50%. Such patients identified in a health care system may be compared to those with the lowest probabilities to initiate engagement strategies.

This study has both strengths and weaknesses. The longitudinal design and time-varying information available on conditions provide a dynamic and informative analysis of chronic conditions and allow for hospitalization and SNF admissions to reoccur in every 6-month interval. In addition, the problem of multiple comparisons when using separate models is avoided by analyzing the 3 outcomes simultaneously. Finally, as we used claims data, missing outcomes or incidence of a new condition would only be due to lacking claims data; furthermore, we were able to address losses due to death by treating mortality as an outcome.

The restriction of our study sample to Medicare fee-for-service participants meant that individuals who participated in managed care or who were not eligible for fee-for-service health care are not represented due to their lack of claims data. Thus, our inference is restricted to those on Medicare fee-for service plans. Conditions that provide more lucrative reimbursement may also be over-represented in claims, although the high prevalence in this study for conditions such as hypertension and hyperlipidemia that are not associated with higher reimbursement would argue against this. We were unable to incorporate the NHATS complex survey sampling design factors and weights for this study due to lack of available software for survey analysis of generalized linear mixed effects joint models. The observational design precludes any inference on causality, although the time-varying information on conditions were temporally prior to the outcomes. Finally, we did not have information on treatments that may mitigate some effects of chronic conditions.

Conclusions and Implications

This study demonstrated a joint model of chronic conditions associated with 3 correlated health care outcomes. We advocate using joint models when studying multiple correlated outcomes and to determine personalized probabilities of outcomes. These absolute measures of probability demonstrate the heterogeneity among older adults for the same outcome with the same characteristics.

Funding

Conflict of Interest

None declared.

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