Patterns of hospitalization risk for women surviving into very old age: findings from the Australian Longitudinal Study on Women's Health

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ABSTRACT (246 words)

BACKGROUND: By 2050, adults aged 80 years and over will represent around 20% of the global population. Little is known about how adults surviving into very old age use hospital services over time.

OBJECTIVES: To examine patterns of hospital usage over a 10-year period for women who were aged 84-89 in 2010 and examine factors associated with increased use.

METHODS: Survey data from 1,936 women from the 1921–1926 cohort of the Australian Longitudinal Study on Women's Health were matched with the state-based Admitted Patients Data Collection. Hospital use profiles we**re determined using repeated measures latent** class analysis.

RESULTS: Four latent class trajectories were identified. One-quarter of the sample were at low hospitalization risk, while 20.6% demonstrated increased hospitalization risk and a further 38.1% had moderate hospitalization risk over time. Only 16.8% of the sample was classified as having high hospitalization risk. Correlates of hospital use for very old women differed according to hospital use class and were contingent on the timing of exposure (i.e. short- or long-term).

CONCLUSION: Despite the perception that older adults place a significant burden on healthcare systems, the majority of women demonstrated relatively low hospital use over an extended period even in the presence of chronic health conditions. High hospitalization risk was found to be concentrated among a small minority of these long-term survivors. The findings suggest the importance of service planning and treatment regimes that take account of the diverse trajectories of hospital use into and through advanced old age.

Key words: women; very old age; hospital; admissions; longitudinal

The health, economic and societal impact of rapid population ageing is a key public health challenge. Adults aged over 60 years will account for 2 billion of the world's population by 2050, rising from 841 million in 2013.[1] More significantly, the proportion of individuals aged 80 years and over is the fastest growing age cohort. The global population of adults aged 80 and over is projected to rise from 14% in 2013 to 19% in 2050, representing a 3-fold increase. This trend is expected to have widespread implications for developing and developed nations, with the gap in life expectancy set to narrow.[1] Currently in Australia, those aged 85 and over represent approximately 2% of the total Australian population,[2] 65% of which are women. Current projections indicate that by 2050 this figure will more than quadruple.[3]

Age is associated with healthcare use,[4] with hospitalisations the primary contributor to healthcare expenditure.[5] The propensity for 'overnight' hospital admissions has been found to increase with age, with approximately 40% of hospital admissions attributed to adults aged 65-74, and 70% for those aged 85 and over.[6] While data from longitudinal population-based studies (and particularly those focused on the very old) are extremely limited, findings from available studies suggest that hospital use by older adults may be far more complex than cross-sectional studies suggest. Sandberg and colleagues[7] argue that older adults represent a heterogeneous group in terms of healthcare utilisation. In their study of Swedish adults aged 60 and over, only 21%-24% had an incident hospital stay over a 6 year period. Among these, total admissions and lengths of stay varied widely.

Understanding the patterns of hospitalisation use of very old adults and identification of factors that contribute to increased hospitalisation is critical to developing targeted interventions to reduce the number of admissions as the ageing population trend amplifies. Increased hospitalisation among older adults has been attributed to a myriad of factors, depending upon the study design and number of variables assessed. Correlates of hospitalisation, (particularly

readmission), have been attributed to clinical characteristics such as chronic conditions and higher disease comorbidity.[8] Non-disease related factors such as self-rated health,[9] functional decline,[10] obesity,[11] smoking,[11] and geriatric problems,[9,10] have also been linked to increased hospitalisations among older adults, albeit less consistently. In addition, psychosocial and demographic factors have been suggested to have an impact on healthcare utilisation, more broadly.[12,13] Examination of predictors of hospital use over time for very old adults is therefore warranted.

RMLCA (an extension of latent class analysis) presents an appropriate lens with which to study hospitalization risk patterns. This form of mixture modelling assumes an underlying grouping exists which divides the population into homogeneous subgroups, of which each individual may fall into one and only one of the groups or categories identified. The application of LCA to repeated measures (RMLCA) enables the identification of different patterns of categorical change when using longitudinal data (3 or more times).[14,15] RMCLA models are used to identify subgroups of individual's patterns of behaviour over time when it is assumed the data will not follow a functional form with respect to time. Using repeated measures latent class analysis (RMLCA) of emergency department data in a U.S. sample, Hastings and colleagues[16] were able to identify 5 distinct patterns of hospital use among adults aged 65 years and over. The largest group consisted of individuals who used primary care often but had low hospital use. The smallest of all groups were those that had average use of primary care but highest hospital and emergency department use. Therefore, with women more likely to survive into very old age,[17] this study aimed to use RMCLA to identify underlying classes of hospital use trajectories over a 10-year period among women aged 74-79 in 2001 and 84-89 years in 2010. Long- and short-term correlates of hospital use in this cohort are also explored.

METHODS

Overview of study design

This study involved data from the 1921-1926 cohort of the Australian Longitudinal Study on Women's Health (ALSWH), a national population-based study of health in Australian women. Women were randomly sampled through the national health insurer's database (Medicare Australia), with women from rural and remote areas sampled at twice the rate as those from urban areas.[18] The cohort has been surveyed every 3 years since 1996. Women who completed follow-up surveys have been found to be largely representative of the population of women in this age group, with a slight over-representation of married, Australian-born and tertiary educated women.[19] This project has ongoing ethical clearance from the University of Newcastle and University of Queensland's Human Research Ethics Committees. Ethical approval for the linkage of ALSWH survey data to the New South Wales (NSW) Admitted Patients Data Collection (APDC) was received from the NSW Population and Health Services Research Ethics Committee and registered with the University of Newcastle.

Participants

A total of 12,432 women from the 1921-1926 cohort completed the baseline survey in 1996 (aged 70-75 years). By 2010, 4,742 (38.1%) of these women had died. Of the remaining 7,690 surviving women 5,126 (66.6%) were not residents of NSW and were excluded as the administrative hospital data was not available. A further 628 women were excluded from the study due to missing baseline survey (1999) data or not residing in the state of NSW for the entire study follow-up period. The final sample consisted of 1,936 (25.2%) who were classified as permanent residents of NSW for the entire 10 years of observation.

Measures

Hospital admissions for the years 2001-2010 were determined from the state-based NSW APDC maintained by the NSW Health Department. ALSWH survey data were linked to the NSW APDC via a master linkage key using a probabilistic algorithm through the Centre for Health Record Linkage (CHeReL).[20] The APDC contains records of all admitted patient services provided by NSW public and private hospitals. Specifically, the data contain information about hospital inpatients including admission and separation dates, and reason for admission (based on ICD-10 codes[21]). It should be noted that in this analysis we only included overnight stays, with procedures such as cataract repair usually only conducted as day procedures. For each year of the observation period (2001-2010) overnight hospital admissions were defined using a binary indicator as we were interested in patterns of admission to hospital (as opposed to a continuous variable which focuses on level of hospital use per year). Hospital admission (any overnight hospital stay in the specified calendar year vs no overnight hospital stay in the year) was used as a repeated indicator of latent class in the RMLCA model. As hospital admission data is routinely collected data for this variable was complete.

ALSWH survey items. Demographic, health behaviour, chronic disease and health-related quality of life factors were included as predictors in the multivariate models. Unless otherwise stated, the variables were measured at both Survey 2 in 1999 (baseline for this analysis) and Survey 5 in 2008. Survey 2 was chosen as the baseline to maintain consistency with the APDC data collection.

Demographic characteristics: Age in years was determined from date of birth. Highest educational qualifications were asked at Survey 1 and was used as a proxy measure of socioeconomic status.[22] Area of residence was assessed according to the Accessibility/Remoteness Index of Australia Plus (ARIA+)[23] which measures distance to services including access to tertiary teaching hospitals, and classified as 'urban' and 'non-

urban'. Marital status was classified as 'widowed' and 'not widowed' in accordance with the major categories for women in this cohort.

Health behaviours: Body Mass Index (BMI) was calculated from self-reported height and weight according to WHO guidelines[24]: 'underweight' (<18.5), 'healthy' (18.5-24.99), and 'overweight/obese' (>25). Smoking history was measured at Survey 2[25] and classified as 'current smoker/ex-smoker' or 'non-smoker'.

Chronic conditions: Physical conditions included being diagnosed/treated for arthritis, heart disease (angina and heart attack), stroke, hypertension, diabetes, and chronic obstructive pulmonary disease (asthma, bronchitis and emphysema) (COPD) in the previous 3 years.

Health-related quality of life: Physical functioning, mental health and general health were determined from the Medical Outcomes Study Short Form-36.[26] Raw scores were linearly transformed to produce dimension scores ranging from 0 to 100 where lower scores reflect poorer functioning in these areas.

Falls within the previous 12 months and urinary incontinence experienced within the previous month were also reported.

Statistical analysis

Patterns of hospital use over the study period were identified using a repeated measures extension of basic latent class analysis (RMLCA)[14]. RMLCA has the potential to enhance our understanding of the varying patterns of overnight hospital stay for older women and estimate the size of the subpopulations of participants who are expected to have similar profiles into mutually exclusive groups. This latent variable technique helps separate error variance from class-relevant variance, thereby providing a person-centred approach. In our study the item indicator, yearly overnight hospital admission status was represented as a binary measure

(0=no overnight hospital admission, 1=having at least one overnight hospital admission) across the 10 time points. Models were fitted successively, estimating 1 to 6 class (or cluster) models. Optimal number of classes in the mixture model was determined by assessing the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), sample size adjusted BIC (aBIC)[27] and the likelihood-ratio G^2 diagnostics.[27] Graphs were used for the interpretability of each of the resultant latent class hospital profiles based on the classes estimated probability of having a hospital admission each year. These were then used as the outcome variable in all further analyses. Testing of unconditional models (without covariates) used maximum likelihood estimation with 20 and 200 random starts to assess stability of the predicted latent class membership. As RMLCA modelling cannot definitively classify participants into only one class (with individuals assigned a posterior probability of membership into each of the latent classes), we used the 'best' variable produced by Proc LCA output which indicates the latent class that is the best match for each participant based on their maximum probability for a particular latent class. Further information on the RMLCA model selection is located in Supplementary Material 1.

Univariate analyses were conducted to assess associations between latent class membership and baseline characteristics using chi-square test ($p<0.05$) and cell contribution to the overall chi-square. Two separate multinomial logistic regression models were then constructed using a backward elimination technique (to assess the fit of the best multivariable model), first with baseline (Survey 2) to examine long–term correlates and then with most recent (Survey 5) factors to examine short–term correlates, regressed onto the dependent variable 'hospitalization risk profile' (i.e. the four factor latent classes that emerged from the RMLCA). The backward elimination selection method was considered appropriate due to the large sample size.

All predictive variables were entered into the model due to their clinical and demographic significance in determining hospital service use. Due to the oversampling of participants from rural and remote areas, all models controlled for area of residence. Model 1 included age, area of residence, highest qualification, marital status, BMI, physical functioning, general and mental health, chronic conditions (arthritis, heart disease, stroke, hypertension, diabetes, COPD; added individually), falls, incontinence and smoking status. Model 2 included all factors from the most recent survey (Survey 5), with the exception of education and smoking (from baseline).

The Hosmer and Lemeshow goodness-of-fit test was used to assess the fit for each model, with odds ratios (95% Confidence Interval). Variables were excluded one at a time based on examination of the Wald statistics. The likelihood ratio test was used to assess if exclusion of a variable at each step made a significant change to the whole model and at each elimination step a comparison of the magnitude of change in the estimated coefficients was assessed to ensure that the excluded variable did not have a major effect on any remaining variable in the model.

Participants' pre- and post-survey information (i.e. data provided at the survey before or after the survey in which there was missing data) was used to fill variables with missing data for predictive factors using a carryover method. The percentage of data this related to can be found in Supplementary Material 2. There was no missing data for overnight hospital admission. All analyses were performed using SAS v9.4 (x64), including Collins and Lanza's PROC LCA (v1.3.2) procedure. [14,28,29]

RESULTS

Hospitalization risk profiles

Of the 1,936 eligible women, 152 (7·9%) did not complete Survey 5 and could not be included in subsequent multivariate analyses. Five models were compared using 1 to 5 latent classes. In comparison to the 1-class model, the greatest reduction in BIC/aBIC statistics appeared between the 3 and 4 class models. Based on statistical and graphical interpretability, the 4 class model was the best fit (see Table S1 and Figure S1 in Supplementary Material 1).[30] This model represented distinctly different patterns and distinguished women with increasing hospital use from women with ongoing moderate use.

The four-class model (Figure 1) included 475 (24·5%) women in Class 1, who were classified as 'low hospitalization risk'. These women had the lowest probability of hospital admissions over the 10-year study period. The second class, 'moderate hospitalization risk' included the largest proportion of women (n=737; 38·1%). The third class (n=399; 20·6%), 'increased hospitalization risk' demonstrated a continued increase in probability of hospital admissions across the study period. Class 4, dubbed 'high hospitalization risk' included 325 (16·8%) women who had consistently high probability of continued hospital admissions over the 10-year follow-up period.

Overall, the proportion admitted increased as the women aged (see Figure 2). Figure 2 also shows the proportionate share of admissions for each latent class. Women in the 'high hospitalization risk' class accounted for 47% of the proportion of overnight hospital admissions in 2001. This proportion however reduced over time, with women from the 'increased hospitalization risk' class accounting for an increasing share of admissions. Despite this, across all participants, only 16-28% of women reported at least 1 hospital admission each year across the observation period.

Reasons for hospital admission

The most common principal diagnoses (ICD-10 codes) across the classes (excluding low hospitalization risk) were related to cardiovascular disease and rehabilitative care (see Table 1). Rehabilitative care (Z50.9) represented approximately 7% of admissions for the 'high' and 'moderate' hospital use classes and almost 10% for women in the 'increased hospitalization risk' class. Similar proportions (around 2-3%) of admission for atrial fibrillation and flutter (I48) were noted for women in both the 'increased' and 'high' hospital use classes.

Characteristics and correlates of hospitalization

Baseline characteristics measured in 1999 for the surviving women are shown in Table 2. Women classified as 'high hospitalization risk' (class 4) were more likely to be widowed ($p=0.0014$), have been diagnosed with arthritis ($p=<0.0001$), heart disease ($p<0.0001$) or stroke ($p=0.005$) compared to women in the other classes. Women defined as 'increased hospitalization risk' (class 3) had the highest prevalence of falls. Low users of hospital services were also less likely to report urinary incontinence than women in either class 2, 3 or 4 (9% vs 18% vs 13% vs 19%, respectively; $p=0.001$). High users of hospital services were also more likely to have more than two comorbidities than women in either class 1, 2, or 3 (29% vs 11% vs 17% vs 14%, respectively; $p=<0.001$). Also shown are the proportions of women in each class who did not return Survey 5, with a higher percentage of these women in the hospital use profile. A statistically significant difference in the proportions of women who died in the 2 years following observation (2011-2012) was found, with a higher percentage of women in the high hospitalization risk class dying in this period (8.7% vs 2.8% vs 2.5% vs 4.4%, respectively; $p<0.001$).

In terms of the number of hospitalisations for each profile, those classified as 'high hospitalization risk' had more than 2-fold the number of average overnight procedures (M(SD)=10.27(5.4)), compared to other women (see Table 2). In addition, women from the

'high hospitalization risk' class had at least 2-fold the average number of bed days (M(SD)=73.23(62.9)) and number of admissions (M(SD)=15.36(9.9)) per participant over the study period. Large variation in hospital admissions existed within members classified as 'high hospitalization risk'. Women with 'low hospitalization risk use' profile were less likely to have an overnight admission compared to the other classes.

Findings from the multinomial analysis examining baseline predictors of latent class membership are shown in Table 3. Significant long-term predictors of not being is the 'low hospitalization risk' class included heart disease, being widowed, as well as general and physical functioning (see Model 1 in Table 3). In particular, women had statistically significant increase in odds of being in the 'high hospitalization risk' class if they had been diagnosed with heart disease (OR=2.38 95%CI: 1.41-3.99) or were widowed (OR:1.69 95%CI:[1.23, 2.32]). Women living in an urban area had decreased odds of being in the 'high hospitalization risk' class (OR:0.72 95%CI:[0.53, 0.99]). Additionally, every 10 unit increase in physical functioning (OR:0.82 95%CI:[0.74, 0.93]) and general health (OR:0.89 95%CI:[0.80, 1.00]) scores decreased the odds of 'high hospitalization risk'.

Similar independent predictors of hospitalization risk were found when short-term factors were examined (see Model 2 in Table 3). Heart disease also predicted increased hospitalization risk as well as high hospitalization risk. Mental Health scores at Survey 5 emerged as a statistically significant predictor of class membership, with a 4% increase in odds of being in the moderate or increased hospitalization risk class for every 10 point increase in mental health score (OR:4.06 95%CI:[1.25, 13.14]).

DISCUSSION

This study examined patterns of overnight hospitalisation for women surviving into very old age using nationally representative longitudinal data. Despite the perception that older adults place significant burden on healthcare systems and resources, this 10-year study found that with respect to overnight hospital admissions, very old women are a heterogeneous group. Importantly, only a small proportion of women were consistently at high risk of hospitalization. Correlates of hospitalisation for very old women differed according to hospitalization risk class and were often contingent on time. The findings indicate that differential trajectories of hospitalization risk have the ability to inform more effective alternate healthcare pathways to hospitalisation. Such approaches may result in better prevention strategies to delay or prevent hospitalisation, and more effective transitions to post-hospitalisation support.

The overall low use of hospitals for this group of women was a key finding. Across all participants, only 16-28% of women reported at least 1 hospital admission per year between 2001 and 2010. This finding is supported by a 6-year Swedish study of healthcare use in men and women aged 60 and over (mean age 76.7 years),[7] but contrasts with studies with shorter follow-periods and specific population groups.[31,32] One Italian study found that 63% of emergency department readmission for over 65 years were hospitalised[32] and another found approximately 50% of over 90 year old Finnish women had at least 1 hospitalisation per year (with multiple admissions due to respite care).[31]

Only a small proportion of women were consistently at high risk of hospitalization in each year. These women accounted for almost half of the proportion of overnight hospital admissions in 2001 and around 34% by 2010. Condelius and colleagues[8] found a similar proportion of frequent hospital users over 1 year in terms of planned and acute hospital admissions in Southern Sweden. A total of 15% reported 3 or more conditions, accounting for 35% of all admissions. High hospitalization risk was attributed to chronic disease multimorbidity and contacts with outpatient care. Although we didn't measure the synergistic impact of chronic

disease combinations we conducted a sensitivity analysis examining weighted multimorbidity[33] and found marginal differences in the respective models. What we did find is that of the conditions examined, cardiovascular-related disease alone was a long-term predictor of high hospitalization risk and a short-term predictor of increased hospitalization risk. This finding is supported by research conducted in other countries.[31,34] It is also consistent with the high proportion of admissions based on ICD-10 code for cardiac cases. Further information on the sensitivity analysis is located in Supplementary Material 3.

Rehabilitation services were another major reason for overnight admissions. The purpose of rehabilitative services is to improve physical functioning and independent living as well as reduce factors such as unnecessary hospital admissions, acute hospital bed days and premature admission to residential aged care facilities. However, it has been found that a large proportion of acute care hospital bed days are attributed to patients who do not meet the criteria for acute level of care, with many deemed more appropriate for transfer to alternate care facilities.[35,36] Provision of intense rehabilitation in specialised rehabilitative settings has been found to improve patient outcomes as well as efficiency.[37,38] The high proportion of very old women in this study admitted to hospital for rehabilitative purposes suggests the need for improvement in the interface between acute care and rehabilitative services. This has important implications for not only patient quality of care but also patient flow.

Prior hospitalisation has been identified as a significant predictor of subsequent hospitalisation in previous research.[7,8] Our study however demonstrated that the largest proportion of women showed moderate risk of hospitalization over time. These represented about 50% of the proportion of admissions in 2001 but only 10% at 2010 follow-up. Roland et al.[39] found a similar pattern in their examination of over 11,000,000 hospital records for National Health Service patients aged 65 and over in the U.K. High users (i.e. 2 or more emergency visits), accounted for 38% of admissions at baseline, but steadily decreased, representing only 3% of

admissions at 5-year follow-up. Our study confirms that for a large portion of very old adults, hospitalisation does not necessarily contribute to a cascade of negative events that lead to increased hospitalisations and risk of mortality. One-quarter of women who survived into very old age had low use and risk of hospitals over the entire study period. These women had significantly better self-rated health than other women, particularly in terms of physical functioning and general health. In the U.S., self-reported poor health has been associated with a 3-fold increase in odds of experiencing any hospital admission and around a 2-fold increase in potentially preventable and repeat admissions.[40-42]

However, inconsistent evidence exists regarding the relationship between functional decline and hospital admission and readmission. A small university hospital-based study suggested that functional abilities may decline prior to hospital admission in older adults,[43] while others have found that in older adults functional decline occurs even in patients functionally independent at admission.[44,45] It has also been suggested that frailty (a biological syndrome of vulnerability that results in progressive, cumulative declines in reserve capacity and fitness across multiple body systems) is at the heart of increased hospitalisations.[46,47] Compared to women with low risk of hospitalization, women in the other latent classes had lower physical functioning and general health in the short-term (i.e. when measured at Survey 5).

Interestingly, of the demographic variables assessed, only widowed marital status was found to be a long-term predictor of hospital use across all latent classes when compared to those with low hospitalization risk. However, this relationship was only significant for increased hospitalization risk when examined at the most recent survey. Loss of a spouse has been found to have long-term impacts on mental and social functioning but not on physical health outcomes or health behaviours.[48,49] Health behaviours such as BMI and smoking as well as educational attainment did not predict hospitalisation over the long- or short-term, with no

significant difference found between the classes at baseline. These factors may be more highly associated with premature mortality.[50,51]

Particular strengths of our study include the longitudinal nature of the data, with older women being able to be followed into very old age. This is important as although current information is required regarding this age group, they are often excluded from research. We were also able to link nationally representative self-reported survey data to a large administrative dataset (involving both public and private hospitals) in order to identify a comprehensive set of predictors that impacted on hospitalisations over time. The study however must be considered in light of a few limitations, including that we were unable to assess symptom severity or clinical stability at discharge. Likewise, we were unable to assess the number and type of medications prescribed. Adverse drug reactions, particularly those related to cardiovascular disorders have been associated with increased hospitalisations.[52] Also, classifying yearly overnight hospital admissions as a binary outcome in the RMLCA may have concealed important patterns of the effects of high hospitalization risk. However, only 10% of women had more than 1 overnight admission per year and a sensitivity analysis performed using overnight hospital admissions as continuous resulted in convergence problems. There is also the potential for bias with some women excluded from the multivariate analyses due to missing data on predictor variables. However, a sensitivity analysis showed that little bias existed with the exception of women with missing data reporting lower educational qualifications and missing data on smoking behaviour. Further, this study was focused solely on women. The patterns of hospital use and factors associated with increased hospitalisations may be markedly different for men. A 1-year study of very old Finnish men and women found that significant differences in hospital patterns exists for men and women, with men spending fewer days in hospital.[31] However, with women more likely to survive into very old age, this cohort is appropriate to study.

With global life expectancies increasing and a wave of baby boomers entering old age, high quality information is required in order to understand who will utilise the bulk of healthcare resources and how we may best reduce costs. This study is 1 step in this process. The identification of 4 different patterns may indicate a need for differential healthcare approaches and strategies for women according to hospitalization risk profile. A high proportionate use of hospitals for rehabilitation may also suggest the need for other facilities for these stays, other than acute care beds. Understanding these factors will assist with future healthcare planning and to ensure future generations age well.

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FIGURE LEGENDS

Figure 1. Four-class model representing yearly hospital admission profiles from 2001–2010 for surviving women from the 1921–1926 cohort. The estimated probability of overnight hospital admissions by year, given latent class membership in the unconditional four class model with class labels in the figure legend (N=1,936). The probability (y-axis) values range from 0 to 1, with 0 reflecting that older women in each class have a 0% probability of having a hospital admission in the respective year and 1 representing a 100% probability of having a hospital admission in the year. **Different symbols have been added for each latent class group for easy classification of classes' trajectory.**

Figure 2. Proportions of overnight admissions accounted for by women according to latent class profile. The total percentage of women admitted to hospital is illustrated by the black line. Overall overnight hospital admissions per year for each of the latent class trajectories are represented as percentages in each of the columns. Note: The latent class group represented as *low* ***hospitalization risk*** have very low rates of hospital use. For most years rate of use is 0.0% and not visible in the graph.