The central role of comorbidity in predicting ambulatory care sensitive hospitalizations*

Barry G. Saver¹, Ching-Yun Wang², Sharon A. Dobie³, Pamela K. Green³, Laura-Mae Baldwin³

1 Department of Family Medicine and Community Health, University of Massachusetts Medical School, Worcester, MA, USA
2 Division of Public Health Sciences, Fred Hutchinson Cancer Research Center, Seattle, WA, USA
3 Department of Family Medicine, University of Washington School of Medicine, Seattle, WA, USA

Correspondence: Barry Saver, M.D., M.P.H., Department of Family Medicine and Community Health, University of Massachusetts, Benedict Building A3-146, 55 Lake Avenue North, Worcester, MA 01655-0002, USA, tel: +1 774 443 3458, fax: +1 774 441 6212, e-mail: barry.saver@umassmed.edu

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Introduction

The construct of ambulatory care sensitive hospitalizations (ACSHs) is based on the idea that some hospitalizations for certain acute conditions should be preventable by timely access to ambulatory care and some for certain chronic conditions should be preventable by good access to high quality care over time to keep these conditions controlled. ACSH rates should, thus, reflect access to care. The Institute of Medicine (IOM) recommended using ACSH rates as measures of access to primary care in 1993.¹ The Agency for Healthcare Research and Quality (AHRQ) has defined Prevention Quality Indicators (PQIs) for adults,² for Healthcare Research and Quality (AHRQ) has defined 14 Prevention Quality Indicators (PQIs) for adults,² for acute and chronic conditions. A recent review found an inverse association between ACSH rates and measures of access to primary care in most studies and noted that most had been carried out in the USA, with non-US studies and those using person-level rather than ecological-level analyses less likely to find this,²¹ but the authors did not address whether the person-level studies controlled for individual comorbidity.

Background: Ambulatory care sensitive hospitalizations (ACSHs) are commonly used as measures of access to and quality of care. They are defined as hospitalizations for certain acute and chronic conditions; yet, they are most commonly used in analyses comparing different groups without adjustment for individual-level comorbidity. We present an exploration of their roles in predicting ACSHs for acute and chronic conditions.

Methods: Using 1998–99 US Medicare claims for 1 069 300 SEER-Medicare control subjects and 1999 Area Resource File data, we modelled occurrence of acute and chronic ACSHs with logistic regression, examining effects of different predictors on model discriminatory power. Results: Flags for the presence of a few comorbid conditions—congestive heart failure, chronic obstructive pulmonary disease, diabetes, hypertension and, for acute ACSHs, dementia—contributed virtually all of the discriminative ability for predicting ACSHs. C-statistics were up to 0.96 for models predicting chronic ACSHs and up to 0.87 for predicting acute ACSHs. C-statistics for models lacking comorbidity flags were lower, at best 0.73, for both acute and chronic ACSHs. Conclusion: Comorbidity is far more important in predicting ACSH risk than any other factor, both for acute and chronic ACSHs. Imputations about quality and access should not be made from analyses that do not control for presence of important comorbid conditions. Acute and chronic ACSHs differ enough that they should be modelled separately. Unaggregated models restricted to persons with the relevant diagnoses are most appropriate for chronic ACSHs.

Study population

This study used 1998–99 US Medicare claims data for SEER-Medicare database control subjects—a US National Cancer Institute-created database of persons aged >65 years who resided in the SEER registry areas, were included in the annual Medicare 5% random sample data files and who did not have a SEER-recorded cancer diagnosis.²³,²⁴ These SEER control subjects are comparable with the general US population aged >65 years except for being more urban, having a higher proportion of foreign-born persons and not having any SEER-diagnosed cancers.²³,²⁵ Medicare claims were obtained from three files: Medicare Provider Analysis and Review (Part A) Claims, Carrier (physician/supplier Part B) Claims and Outpatient (institutional Part B) Claims. Data from 1998 were used to produce comorbidity and utilization-based predictors for 1999 ACSHs. To ensure complete data capture, subjects had to be full-year enrollees in fee-for-service
Outcome measures

We based our outcome measures on the AHRQ PQIs, which use discharge diagnosis codes to define eligible hospitalizations.24 As the IOM report lists avoidable hospitalization for acute and chronic conditions as separate indicators,1 and they presumably represent different types of access–urgent access to primary care when an acute episode occurs and good access to primary care over time for management of chronic conditions—we created two ACSH measures, one for occurrence of at least one ‘acute ACSH’ (bacterial pneumonia, dehydration, or urinary tract infection) and one for occurrence of at least one ‘chronic ACSH’ [diabetes, hypertension, asthma, CHF, or chronic obstructive pulmonary disease (COPD)].

We excluded perforated appendicitis, as more than one-fourth of cases were missing the required ICD-9 fourth digit indicating perforation status. The small numbers (~60 perforations/120–160 cases per year) would not alter any of our findings. We excluded the angina PQI, having found a 75% drop between 1993 and 1999 that appeared to be due to coding and practice changes.26

Key predictor—comorbidity

For the study comparing care for colorectal cancer patients with control subjects,22 for which our data set was developed, we had computed the Romano adaptation of the Charlson comorbidity index.27,28 Setting a comorbidity flag (see Supplementary Appendix 1) required a diagnosis to be coded on one inpatient claim or two non-laboratory outpatient claim separated by >30 days. We created an additional flag for hypertension, as the Romano–Charlson index does not include hypertension; yet, PQI 7 is hospitalization for uncontrolled hypertension. We represented comorbidity primarily using the individual Romano–Charlson condition flags plus the hypertension flag, based on claims during the prior year. We dropped the flag for AIDS, as too few subjects (n = 20) carried this diagnosis. Secondly, we evaluated models using the Charlson index plus the hypertension flag.

Other predictors

Predictors were chosen from the available data based on Andersen’s Behavioural Model,29,30 classified as primarily reflecting predisposing, enabling and need factors. Predisposing factors were age, gender and racial/ethnic background, derived from Medicare enrollment files.

Enabling factors included rural–urban residence, state of residence, availability of health care services and continuity of care. Residence was classified by ZIP code according to the Rural-Urban Commuting Areas31 as urban-focused, large rural city/town-focused, small rural town-focused or isolated small rural town-focused. County-level availability of services was modelled using 1999 Area Resource File data as per capita numbers of family physicians and general practitioners (GPs), general internists and acute short-term hospital beds, with measures grouped into quintiles. We derived an empirical measure of continuity of primary care: having the same PCP provide the plurality of primary care in 2 successive years. We defined PCPs as family physicians, general internists or GPs using specialty data from the American Medical Association’s Physician Masterfile or, if no data were in the Masterfile, using the specialty code in the Medicare claims data.

As Medicare data lack individual-level information on income and education, we used census-derived, ZIP code-based surrogates for educational attainment and household income: race-specific percentage of the population aged ≥25 years with at least a high school education (<50%, 50–75%, >75%)12 and age-specific median household annual income (≤$25 000, $25 001–$35 000, $35 001–$45 000 or >$45 000).

Need factors in addition to comorbidity were original source of Medicare eligibility [disability or end-stage renal disease (ESRD) vs. age], number of outpatient visits in the prior year (though visits also reflect propensity and ability to obtain care) and having had at least one acute ACSH or one chronic ACSH in the prior year.

Analyses

To facilitate interpretation of results and allow for non-linear relationships, continuous variables were categorized—e.g. measures of local resource availability were grouped into quintiles. Significance of bivariate associations with occurrence of any acute and any chronic ACSH was assessed with chi-square tests. Analyses of predictive accuracy were conducted with proc logistic using 1998 data for comorbidity and utilization and 1999 data for outcomes. We constructed logistic models predicting occurrence of at least one acute or one chronic ACSH during 1999, successively adding the groups of predisposing, enabling and then need factors other than comorbidity and prior year ACSHs. We then added comorbidity, represented as either separate comorbidity flags or the Charlson index plus the hypertension flag, plus previous-year ACSH flags. We also evaluated models containing only comorbidity and previous year ACSH flags. As <3% of subjects had an acute or chronic ACSH, odds ratios will be good approximations of true relative risks. Model improvement was gauged by changes in the c-statistic.

To represent plausible population sizes that might be found when analysing practices with either a few or a moderate number of providers and to provide information about potential overfitting, we created pairs of random subsamples of 1000 and 5000 observations each that we used as training and validation sets. As many of our predictors may not be available in all settings, and our modelling indicated that just a few comorbidity flags—CHF, COPD, diabetes, hypertension and, for acute ACSHs, dementia—provided nearly all the discriminatory power, we used these five flags plus age and gender to create models with the training sets and used these coefficients to produce probability estimates for the validation set populations. We computed c-statistics to measure model discrimination in both the derivation and validation subsets.

Analyses were conducting using SAS for Windows version 9.2. The study was reviewed and approved by the University of Washington’s Institutional Review Board.

Results

Table 1 shows selected characteristics of the study population in 1999. Comparing individual racial/ethnic groups to the rest of the population, whites were significantly underrepresented and Blacks overrepresented among those experiencing acute and chronic ACSHs. Hispanics were overrepresented among those having a chronic ACSH and Asians/Pacific Islanders underrepresented among those having an acute ACSH. Older and sicker persons were much more likely to have an ACSH, particularly persons with CHF, COPD, diabetes, heart disease and kidney disease. Having had an ACSH in the previous year was also strongly associated with having an ACSH, particularly the same kind of ACSH. Different levels of the Area Resource File-based measures of primary care and hospital bed availability and numbers of outpatient visits in the previous year were significantly associated with risk of both types of ACSH, but not in any fashion suggesting trends, nor was the measure of continuity of primary care significantly associated with having either ACSH (data not shown).

Table 2 shows odds ratios for predisposing factors and comorbidity from models predicting odds of having had at least one acute ACSH during 1999. Model 1, containing only predisposing factors, showed moderate discrimination, with a
c-statistic of 0.684. Both blacks and Hispanics had significantly higher odds of an acute ACSH compared with whites. Model 2 included all predictors except comorbid condition flags and previous year ACSHs but included a flag for disability or ESRD vs. age as source of Medicare eligibility. It had moderately better discrimination, with a c-statistic of 0.724. In this model, black–white differences were barely significant, and Hispanic–white differences were no longer significant. Model 3, containing flags for comorbidity and previous year ACSHs (see Supplementary Appendix 2 for complete model), showed markedly better discrimination, with a c-statistic of 0.873. Virtually, all of this improvement came from adding the comorbidity flags; although having a previous year acute ACSH was highly significant and had an odds ratio of 2.67, and previous year chronic ACSH predicted a modestly lower likelihood, the c-statistic for a model without the previous year ACSH flags was barely lower–0.867 (data not shown). Given the large effect of the comorbidity flags, we show Model 4, in which we removed all enabling and need factors except the comorbid condition flags; the c-statistic of 0.867 was barely lower for Model 3. The c-statistic for a model with the Charlson index and a hypertension flag added to Model 2 was only 0.756 (data not shown).

Table 3 shows the same set of models predicting the occurrence of at least one chronic ACSH. The first two models had virtually identical c-statistics as the corresponding acute ACSH models in table 2.
However, Model 3, with comorbidity indicators added (see Supplementary Appendix 2 for complete model), yielded a much higher c-statistic of 0.960. As for acute ACSHs, Model 4, containing only predisposing factors and the comorbidity flags, showed that virtually all of the improved discrimination came from controlling for comorbidity, despite a highly significant previous year chronic ACSH indicator with an odds ratio of 1.23. Adding the Charlson index and a hypertension flag to the second model again did not perform nearly as well, although the c-statistic of 0.807 (data not shown) was somewhat higher than that obtained for the corresponding acute ACSH model.

To evaluate how much our findings for chronic ACSHs were driven by the near tautology of being predicted by conditions that by the comorbidity flags, and some conditions—particularly CHF and COPD—have frequent exacerbations that can lead to hospitalization. We computed c-statistics for pairs of derivation and validation subsamples of 1000 and 5000 randomly selected observations. As a number of factors were too uncommon to model with 1000 observations, and many settings lack information on race and ethnicity, we evaluated reduced models containing only comorbidity flags and previous year ACSHs except comorbidity flags and previous year ACSHs, but not those containing the Charlson index or hypertension flag. The central role of comorbidity was virtually as good as in models including all the other factors, plus age and gender. As shown in Table 4, C-statistics for these models were similar to those of Models 3 and 4 in Tables 2 and 3, with relatively narrow confidence intervals.

### Discussion

We found that a simple set of comorbidity flags had far greater predictive power for acute and chronic ACSHs than any other factors. Model discrimination using just a limited set of comorbidity flags was virtually as good as in models including all the other factors, even though some of those factors were significantly associated with having an ACSH. This should not be surprising for chronic ACSHs, as they are dependent on having a number of the conditions represented by the comorbidity flags, and some conditions—particularly CHF and COPD—have frequent exacerbations that can lead to hospitalization.
This is part of the rationale for ACSHs as measures of quality and access. However, the similar finding for acute ACSHs is less expected, even acute ACSHs, failure to address underlying comorbidity before attempting to measure effects of care on ACSH rates has a high probability of producing misleading results driven by comorbidity. Several studies have observed comorbidity to increase the odds of having ACSHs markedly among Medicare beneficiaries with CHF,\textsuperscript{33} diabetes,\textsuperscript{34} dementia\textsuperscript{35} and overall.\textsuperscript{36} Laditka\textsuperscript{37,38} found a variety of comorbid conditions, self-rated health status, previous discharge in the past 90 days and days since previous discharge all to be highly significant predictors of any ACSH among older adults. Bindman et al.\textsuperscript{37} reported that individual adjustment for comorbidity did not substantially alter their findings on association of interruptions in Medicaid coverage with ACSH risk among Californians aged
The central role of comorbidity

18–64 years, but members of the two groups were similar—the same subjects could even contribute time to both groups. The differences in findings for acute and chronic ACSHs, including different degrees of model discrimination and substantially different coefficients for many factors as reflected in Tables 2 and 3, indicate that, per their original conceptualization and as recommended by the IOM, they should be examined separately and not lumped together. Many of these events are sufficiently uncommon that separate analysis for each PQI measure is frequently not practicable. One might argue that controlling for comorbidity is overadjustment, as good care might prevent developing these conditions, but attributing comorbidity to patients’ current providers or plans is unjustifiable, given frequent changes. Furthermore, it is hard to imagine how chronic ACSHs can be prevented in persons lacking the relevant diagnoses. Thus, for chronic ACSHs, the most appropriate approach would be measure-specific analyses restricted only to persons with the relevant condition, controlling for other comorbidities. Even this cannot compensate for any differences in severity among groups being compared.

Our analyses are subject to a number of limitations. First, we did not set out to develop the optimal set of comorbidity indicators to predict ACSHs but rather took advantage of indicators we had created for other purposes. However, our work suggests that a few, ‘usual suspect’ condition flags provide nearly all of the predictive power. Second, our analyses were conducted using 1998–99 data from SEER-Medicare control subjects. Although there have been some changes in diagnosis and treatment of these conditions in the interim, it is hard to imagine any changes that would affect our findings about comorbidity as the major predictor of these hospitalizations. As most persons having cancer were excluded from this group, we cannot address whether cancer status is also a strong predictor of these hospitalizations. Further studies are needed to determine whether our findings apply to younger or uninsured persons, but the majority of ACSHs occur in persons aged ≥65 years. Third, we used ecological surrogates for education and income and lacked individual-level data, e.g. health status, self-reported access measures and socio-economic factors, that might be important predictors of ACSHs. Laditka found self-reported health status, but not years of education, a significant ACSH predictor. Fourth, county-level measures of health services capacity do not necessarily reflect factors most directly connected with timely access to care, such as travel time to providers’ offices, evening and weekend hours, and appointment availability. Finally, although the issues we identified pertaining to the importance of comorbidity and differences between acute and chronic ACSH measures are likely to be universal, health care system factors undoubtedly affect rates and preventability of these hospitalizations. Our analyses, limited to US Medicare data, cannot address the roles of system factors in other countries—or even within different systems of care in the USA.

Many studies have used ACSHs to assess differences in access between different populations without adjusting for individual-level comorbidity. Our findings clearly indicate that ACSH measures should not be used without control for individual-level comorbidity, absent clear evidence that comorbidity is equivalent across the populations compared—rarely true for different nations or racial, ethnic or socio-economic groups. The AHRQ updated the definitions of their three diabetes-related PQIs to be based on the population of persons with diabetes, but not any of the other PQI measures. Despite ACSHs’ face validity, our findings question their construct validity, as many have used and are using them. Combining acute and chronic ACSHs into an omnibus measure does not appear appropriate, either on theoretical or empirical grounds. Condition-specific analyses restricted to persons diagnosed with the relevant condition for PQIs related to chronic health conditions would be most appropriate to eliminate condition prevalence as a potential confounder. A recent study compared ACSH rates and trends between Denmark and Kaiser Permanente in the USA, attributing differences to care patterns, but prevalence of comorbid conditions could substantially affect the differences found. They also noted a 9-fold higher Danish rate of angina hospitalizations. Given our previously demonstrated findings on the drop in US hospitalizations qualifying for the angina ACSH in the 1990’s unrelated to prevention of angina or admission for chest pain, this further highlights the need to use ACSH measures with greater care and better validation than is often the case now.

The remarkably high c-statistics of our models, particularly for predicting chronic ACSHs, strongly suggest developing and evaluating interventions to reduce these hospitalizations among persons identified as being at high risk using such models. There is a clear need for studying health care access and quality at the level experienced by individuals to learn if, when, and how potentially preventable hospitalizations can be prevented.

Supplementary Data

Supplementary data are available at EURPUB online.

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Conflicts of interest: None declared.

Key points

- A very limited set of comorbidities provides virtually all of the discriminative power in models predicting ACSHs, with c-statistics of 0.87 for predicting acute ACSHs and 0.96 for chronic ACSHs.
- Acute and chronic ACSHs are different enough that they should be analysed separately and not lumped together.
- Under most circumstances, ACSH-based analyses should control for individual-level comorbidity and study each
chronic ACSH separately in analyses limited to persons having the relevant chronic condition.
• Validity of ACSH-based analyses needs to be tested and proven, not assumed, when comparing different populations or different periods.

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