European Journal of Public Health, Vol. 24, No. 1, 66–72

doi:10.1093/eurpub/ckt019 Advance Access published on 28 March 2013

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

Barry G. Saver[1], Ching-Yun Wang[2], Sharon A. Dobie[3], Pamela K. Green[3], Laura-Mae Baldwin[3]

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

*Part of this work was presented at the 2010 annual research meeting of AcademyHealth, Boston, MA on June 29, 2010.

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 106 930 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.

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 14 Prevention Quality Indicators (PQIs) for adults,[2,3] both for acute conditions, such as bacterial pneumonia and urinary tract infection, and for chronic conditions, such as diabetes and congestive heart failure (CHF).

US ACSH rates have been shown to be higher for the uninsured and Medicaid beneficiaries vs. those with private health insurance,[4] for persons losing Medicaid coverage vs. those retaining it,[5] for persons living in lower vs. higher income areas,[6] among persons of lower vs. higher socioeconomic status,[7] for black and Hispanic Americans vs. non-Hispanic whites[7–12] and in areas with fewer primary care providers (PCP).[13,14] Despite known racial/ethnic and socio-economic variation in the prevalence of many chronic health conditions and the condition-specific nature of many ACSHs, relatively few studies have used individual-level measures of comorbidity, e.g. not controlling for at all for comorbidity,[9,15–17] using ecological rather than individual-level adjustment[10,18,19] or using a crude measure such as disabled or not[20] rather than indicators of the presence of specific relevant comorbid 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.

As part of a study, The Non-Cancer Care of Elderly Colorectal Cancer Patients, comparing care for colorectal cancer patients with control subjects,[22] we assessed comorbidity as a predictor of ACSHs.

Methods

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

parts A and B Medicare during 1998 and 1999 up to the time of death, if any.

Outcome measures

We based our outcome measures on the AHRQ PQIs, which use discharge diagnosis codes to define eligible hospitalizations.[2] 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 claims 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. Secondarily, 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 Areas[31] 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%)[32] 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

Table 1 Characteristics of the study population in 1999

Predictor	Overall population		Any acute ACSH in 1999	Any chronic ACSH in 1999
	N	%		
Total	1 06 930		3110	2728
Race/ethnicity			****	****
White	89 079	83.3%	81.5%	76.4%
Black	7130	6.7%	8.9%	13.6%
Asian/Pacific Islander	5091	4.8%	3.5%	4.2%
Hispanic	2,542	2.4%	2.8%	3.2%
Other	3088	2.9%	3.2%	2.6%
Age			****	****
66–69	17 488	16.4%	6.8%	8.9%
70–74	30 013	28.1%	16.5%	19.3%
75–79	25 721	24.1%	19.9%	22.8%
>80	33 708	31.5%	56.8%	49.0%
Male	40 018	37.4%	35.6%*	36.0%
Median household income in ZIP code			****	****
Up to $25 000	37 811	35.4%	49.0%	49.6%
$25 001–$35 000	37 414	35.0%	33.9%	32.6%
$35 001–$45 000	17 502	16.4%	10.2%	10.9%
>$45 000	14 203	13.3%	6.9%	6.9%
Percentage of high school graduates in ZIP code			****	****
<50%	3774	3.5%	5.2%	4.9%
50–75%	16 685	15.6%	18.7%	21.3%
>75%	86 471	80.9%	76.1%	73.8%
Urban/rural residence			*	
Urban	87 520	81.8%	79.7%	82.9%
Large rural	8141	7.6%	8.8%	6.5%
Small rural	5947	5.6%	6.2%	5.4%
Remote rural	5322	5.0%	5.3%	5.2%
ESRD or disability as source of medicare eligibility	6388	6.0%	9.9%****	11.7%****
Any acute ACSH in 1998	2207	2.1%	11.2%****	7.5%****
Any chronic ACSH in 1998	2183	2.0%	6.8%****	19.3%****
Comorbidities				
Cerebrovascular disase	4933	4.6%	17.6%****	15.8%****
CHF	8113	7.6%	42.6%****	79.4%****
COPD	7919	7.4%	39.2%****	44.4%****
Dementia	3433	3.2%	19.0%****	10.7%****
Diabetes without complications	9105	8.5%	24.5%****	37.4%****
Diabetes with complications	2078	1.9%	6.6%****	19.9%****
Old MI	1843	1.7%	7.4%****	13.6%****
Acute MI	1234	1.2%	4.8%****	7.3%****
Mild-moderate liver disease	257	0.2%	1.0%****	1.0%****
Severe liver disease	170	0.2%	0.6%****	0.5%****
Renal disease	1321	1.2%	6.5%****	12.8%****
Non-metastatic cancer	1120	1.0%	3.3%****	2.3%****
Metastatic cancer	193	0.2%	1.0%****	[a]
Paraplegia	393	0.4%	1.8%****	1.3%****
Ulcers	1,258	1.2%	5.1%****	5.7%****
Vascular disease	4,408	4.1%	13.2%****	19.6%****
Hypertension	56,618	52.9%	69.5%****	80.4%****
Rheumatologic conditions	1,140	1.1%	3.1%****	2.6%****
AIDS	20	0.0%	0.0%	0.0%

ACSH, Ambulatory Care Sensitive Hospitalisation; AIDS, Acquired Immune Deficiency Syndrome; CHF, Congestive Heart Failure; COPD, Chronic Obstructive Pulmonary Disease; ESRD, End-Stage Renal Disease; FP, Family Physician; GP, General Practitioner; MI, Myocardial Infarction.

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; ****$P < 0.0001$.

Note: Significance was evaluated with 2× N chi-square tests for heterogeneity.

a: Omitted owing to SEER-Medicare guidelines on minimum cell size for reporting.

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.

Table 2 Models predicting likelihood of having an ACSH

	Model 1 Predisposing factors	Model 2 Model 1 + enabling and need factors[a] except comorbidity flags and previous year ACSHs	Model 3 Model 2 + comorbidity flags and previous year ACSHs	Model 4 Model 1 + comorbidity flags
C-statistic (95% CI)	**0.68 (0.67, 0.69)**	**0.72 (0.72, 0.74)**	**0.87 (0.86, 0.88)**	**0.87 (0.86, 0.87)**
Predictor	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Black	1.42 (1.25, 1.62)	1.18 (1.01, 1.36)	0.97 (0.82, 1.13)	1.04 (0.90, 1.20)
Asian/Pacific islander	0.88 (0.73, 1.07)	1.00 (0.81, 1.24)	1.00 (0.80, 1.25)	0.87 (0.71, 1.07)
Hispanic	1.54 (1.24, 1.92)	1.15 (0.89, 1.48)	1.23 (0.94, 1.61)	1.43 (1.13, 1.81)
Other	1.16 (0.95, 1.43)	1.16 (0.92, 1.47)	1.21 (0.94, 1.55)	1.21 (0.97, 1.50)
White	1	1	1	1
Age 66–69	1	1	1	1
Age 70–74	1.41 (1.20, 1.66)	1.40 (1.19, 1.64)	1.28 (1.09, 1.52)	1.26 (1.07, 1.49)
Age 75–79	1.97 (1.69, 2.31)	1.77 (1.50, 2.08)	1.54 (1.29, 1.83)	1.54 (1.30, 1.81)
Age >80	4.08 (3.53, 4.72)	3.66 (3.14, 4.27)	2.72 (2.31, 3.21)	2.73 (2.34, 3.18)
Male	1.05 (0.98, 1.14)	1.07 (0.99, 1.15)	0.95 (0.87, 1.03)	0.95 (0.87, 1.03)
Disability or ESRD vs. age as original source of Medicare eligibility		1.77 (1.56, 2.01)	1.30 (1.13, 1.49)	
Had an acute ACSH in 1998			2.67 (2.31, 3.07)	
Had a chronic ACSH in 1998			0.80 (0.67, 0.95)	
CHF			3.31 (3.02, 3.64)	3.38 (3.08, 3.71)
COPD			4.43 (4.05, 4.84)	4.59 (4.20, 5.00)
Uncomplicated diabetes mellitus			1.86 (1.67, 2.06)	1.85 (1.66, 2.05)
Complicated diabetes mellitus			1.01 (0.84, 1.22)	0.98 (0.82, 1.18)
Hypertension			1.35 (1.23, 1.47)	1.30 (1.20, 1.42)
Dementia			3.58 (3.19, 4.01)	3.66 (3.27, 4.10)
Cerebrovascular disease			1.49 (1.33, 1.68)	1.50 (1.34, 1.68)
Paralytic/paraplegic conditions			1.58 (1.13, 2.20)	1.62 (1.17, 2.25)
Acute MI, current year			0.86 (0.70, 1.05)	0.87 (0.71, 1.06)
Coded diagnosis of old MI			1.42 (1.20, 1.68)	1.39 (1.18, 1.64)
Vascular disease other than cardiac or cerebrovascular			1.13 (0.99, 1.28)	1.12 (0.99, 1.28)
Collagen vascular disease			2.04 (1.61, 2.60)	2.10 (1.66, 2.66)
Chronic renal failure			1.54 (1.28, 1.86)	1.51 (1.25, 1.81)
Mild liver disease			1.72 (1.08, 2.74)	1.60 (1.00, 2.55)
Moderate-severe liver disease			1.07 (0.60, 1.92)	1.12 (0.63, 1.99)
Cancer, without metastases			1.77 (1.38, 2.29)	1.75 (1.37, 2.25)
Cancer, with metastases			2.43 (1.50, 3.91)	2.53 (1.58, 4.05)
Peptic ulcer disease			1.59 (1.30, 1.93)	1.66 (1.36, 2.02)

ACSH, Ambulatory Care Sensitive Hospitalization; ESRD, End-Stage Renal Disease; MI, Myocardial Infarction.
a: Enabling factors are ZIP-code level measures of educational attainment and income, rural/urban residence, county-level per capita numbers of: (i) family and GPs; (ii) general internists; and (iii) hospital beds, continuity with plurality of care PCP and state of residence. Need factors are original source of Medicare eligibility (disability or ESRD vs. age) and number of outpatient visits in the previous year.

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 2.82, with previous year acute ACSH having an odds ratio of 1. 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 are used in defining the ACSHs, we conducted supplementary analyses excluding persons with diagnoses of CHF, COPD and diabetes. This reduced the denominator population by 19% and the numerators of acute and chronic ACSHs by 71 and 97%, respectively. For chronic ACSHs, c-statistics for acute ACSH Models 3 and 4 were 0.80 and 0.79, respectively; for chronic ACSHs, they were 0.88 and 0.87, driven almost entirely by the flags for hypertension and cerebrovascular disease.

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 for the conditions contributing most to discriminatory power, 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.

Table 3 Models predicting likelihood of having a chronic ACSH

	Model 1 Predisposing factors	Model 2 Model 1 + enabling and need factors* except comorbidity flags and previous year ACSHs	Model 3 Model 2 + comorbidity flags and previous year ACSHs	Model 4 Model 1 + comorbidity flags
C-statistic (95% CI)	**0.67 (0.66, 0.68)**	**0.73 (0.72, 0.74)**	**0.96 (0.96, 0.96)**	**0.96 (0.96, 0.96)**
Predictor	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Black	2.34 (2.08, 2.62)	1.89 (1.64, 2.16)	1.61 (1.36, 1.91)	1.76 (1.52, 2.03)
Asian/Pacific islander	1.09 (0.90, 1.32)	1.19 (0.96, 1.48)	1.26 (0.98, 1.63)	1.26 (1.00, 1.58)
Hispanic	1.76 (1.41, 2.19)	1.49 (1.15, 1.93)	1.48 (1.07, 2.04)	1.50 (1.14, 1.98)
Other	0.99 (0.78, 1.26)	1.04 (0.79, 1.35)	1.04 (0.75, 1.44)	1.04 (0.78, 1.39)
White	1	1	1	1
Age 66–69	1	1	1	1
Age 70–74	1.26 (1.08, 1.47)	1.24 (1.07, 1.45)	1.10 (0.91, 1.32)	1.06 (0.88, 1.28)
Age 75–79	1.73 (1.49, 2.01)	1.47 (1.26, 1.73)	1.26 (1.03, 1.53)	1.23 (1.03, 1.48)
Age >80	2.62 (2.28, 3.02)	2.25 (1.94, 2.62)	1.50 (1.25, 1.81)	1.48 (1.25, 1.76)
Male	1.03 (0.95, 1.12)	1.05 (0.97, 1.14)	0.85 (0.77, 0.94)	0.85 (0.77, 0.94)
Disability or ESRD vs. age as original source of Medicare eligibility		1.88 (1.66, 2.13)	1.20 (1.03, 1.41)	
Had an acute ACSH in 1998			1.00 (0.82, 1.21)	
Had a chronic ACSH in 1998			2.82 (2.44, 3.26)	
CHF			25.8 (23.0, 28.9)	25.8 (23.2, 28.8)
COPD			3.49 (3.15, 3.87)	3.41 (3.09, 3.76)
Uncomplicated diabetes mellitus			1.88 (1.68, 2.11)	1.79 (1.60, 2.00)
Complicated diabetes mellitus			4.07 (3.45, 4.80)	3.93 (3.35, 4.61)
Hypertension			1.72 (1.54, 1.93)	1.70 (1.52, 1.90)
Dementia			1.27 (1.08, 1.49)	1.24 (1.05, 1.45)
Cerebrovascular disease			0.94 (0.82, 1.08)	0.90 (0.79, 1.04)
Paralytic/paraplegic conditions			0.84 (0.54, 1.31)	0.88 (0.57, 1.35)
Acute MI, current year			0.67 (0.55, 0.81)	0.70 (0.58, 0.84)
Coded diagnosis of old MI			1.94 (1.65, 2.28)	2.02 (1.73, 2.36)
Vascular disease other than cardiac or cerebrovascular			1.45 (1.26, 1.65)	1.34 (1.17, 1.52)
Collagen vascular disease			1.25 (0.91, 1.71)	1.15 (0.85, 1.56)
Chronic renal failure			1.84 (1.54, 2.20)	1.81 (1.53, 2.16)
Mild liver disease			1.16 (0.67, 2.02)	1.19 (0.70, 2.03)
Moderate-severe liver disease			0.49 (0.24, 1.00)	0.48 (0.24, 0.98)
Cancer, without metastases			1.30 (0.93, 1.82)	1.30 (0.94, 1.79)
Cancer, with metastases			0.62 (0.26, 1.46)	0.64 (0.28, 1.48)
Peptic ulcer disease			1.29 (1.03, 1.62)	1.32 (1.05, 1.65)

ACSH, Ambulatory Care Sensitive Hospitalization; ESRD, End-Stage Renal Disease; MI, Myocardial Infarction.
a: Enabling factors are ZIP-code level measures of educational attainment and income, rural/urban residence, county-level per capita numbers of: (i) family and GPs; (ii) general internists; and (iii) hospital beds, continuity with plurality of care PCP and state of residence. Need factors are original source of Medicare eligibility (disability or ESRD vs. age) and number of outpatient visits in the previous year.

Table 4 C-statistics (95% confidence intervals) for derivation and validation subsamples[a]

Sample size	Acute ACSH		Chronic ACSH	
	Derivation	Validation	Derivation	Validation
1000	0.89 (0.84, 0.94)	0.91 (0.85, 0.96)	0.97 (0.95, 0.99)	0.96 (0.93, 1)
5000	0.87 (0.84,0.90)	0.87 (0.84, 0.90)	0.96 (0.95, 0.97)	0.93 (0.90, 0.96)

ACSH, Ambulatory Care Sensitive Hospitalization.
a: Models controlled for age, gender, CHF, chronic obstructive pulmonary disease, diabetes, hypertension and dementia.

This is part of the rationale for ACSHs as measures of quality and access. However, the similar finding for acute ACSHs is less expected, and the importance of dementia in addition to CHF, COPD, diabetes and hypertension highlights the role of individual characteristics in these hospitalizations.

It is not unexpected that experiencing a chronic ACSH would strongly predict risk in the following year but perhaps less expected that a prior acute ACSH should be associated with having a subsequent acute ACSH, as these indicators were chosen to represent acute, not chronic, conditions. Underlying factors clearly predispose vulnerable people to experiencing these acute conditions recurrently (e.g. persons with chronic lung disease are more prone to pneumonia), and underlying frailty (e.g. dementia) may substantially increase the risk of hospitalization when a relevant acute condition develops. Given how strongly comorbidity predicts 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,[33] diabetes,[34] dementia[35] and overall.[36] Laditka[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.*[5] 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

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 $\geq$65 years.[39] 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[38] 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.[40] 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,[17] 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,[26] 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.

Acknowledgements

This study used the linked SEER-Medicare database. The interpretation and reporting of these data are the sole responsibility of the authors. The authors acknowledge the efforts of the Applied Research Programme, NCI; the Office of Research, Development and Information, CMS; Information Management Services (IMS), Inc.; and the Surveillance, Epidemiology, and End Results (SEER) Programme tumour registries in the creation of the SEER-Medicare database.

The collection of the California cancer incidence data used in this study was supported by the California Department of Public Health as part of the statewide cancer-reporting programme mandated by California Health and Safety Code Section 1 03 885; the National Cancer Institute's Surveillance, Epidemiology and End Results Programme under contract N01-PC-35136 awarded to the Northern California Cancer Center, contract N01-PC-35 139 awarded to the University of Southern California, and contract N02-PC-15 105 awarded to the Public Health Institute; and the Centers for Disease Control and Prevention's National Programme of Cancer Registries, under agreement #U55/CCR921930-02 awarded to the Public Health Institute. The ideas and opinions expressed herein are those of the author(s) and endorsement by the State of California, Department of Public Health the National Cancer Institute, and the Centers for Disease Control and Prevention or their Contractors and Subcontractors is not intended nor should be inferred. The authors acknowledge the efforts of the Applied Research Programme, NCI; the Office of Research, Development and Information, CMS; Information Management Services (IMS), Inc.; and the Surveillance, Epidemiology, and End Results (SEER) Programme tumour registries in the creation of the SEER-Medicare database.

Funding

This work was supported in part by the National Cancer Institute at the National Institutes of Health [grant number 1 R01 CA104935].

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.

References

1 Institute of Medicine (U.S.). Committee on monitoring access to personal health care services. In: Millman ML, editor. *Access to Health Care in America*. Washington, D.C.: National Academy Press, 1993.

2 Agency for Healthcare Research and Quality. Prevention quality indicators: technical specifications. Department of Health and Human Sevices, Agency for Healthcare Quality and Research, 2006. Available at: http://www.qualityindicators.ahrq.gov/downloads/pqi/pqi_technical_specs_v30b.pdf. (2 October 2006, date last accessed).

3 Agency for Healthcare Research and Quality. Guide to prevention quality indicators: hospital admission for ambulatory care sensitive conditions. Department of Health and Human Services, Agency for Healthcare Research and Quality, 2006. Available at: http://www.qualityindicators.ahrq.gov/downloads/pqi/pqi_guide_v30a.pdf. (2 October 2006, date last accessed).

4 Weissman JS, Gatsonis C, Epstein AM. Rates of avoidable hospitalization by insurance status in Massachusetts and Maryland. *JAMA* 1992;268:2388–94.

5 Bindman AB, Chattopadhyay A, Auerback GM. Interruptions in medicaid coverage and risk for hospitalization for ambulatory care-sensitive conditions. *Ann Intern Med* 2008;149:854–60.

6 Billings J, Zeitel L, Lukomnik J, et al. Impact of socioeconomic status on hospital use in New York City. *Health Aff (Millwood)* 1993;12:162–73.

7 Blustein J, Hanson K, Shea S. Preventable hospitalizations and socioeconomic status. *Health Aff (Millwood)* 1998;17:177–89.

8 Gaskin DJ, Hoffman C. Racial and ethnic differences in preventable hospitalizations across 10 states. *Med Care Res Rev* 2000;57(Suppl. 1):85–107.

9 Pappas G, Hadden WC, Kozak LJ, Fisher GF. Potentially avoidable hospitalizations: inequalities in rates between US socioeconomic groups. *Am J Pub Health* 1997;87:811–6.

10 Laditka JN, Laditka SB, Mastanduno MP. Hospital utilization for ambulatory care sensitive conditions: health outcome disparities associated with race and ethnicity. *Soc Sci Med* 2003;57:1429–41.

11 Shi L, Samuels ME, Pease M, et al. Patient characteristics associated with hospitalizations for ambulatory care sensitive conditions in South Carolina. *South Med J* 1999;92:989–98.

12 Laditka JN, Laditka SB. Race, ethnicity and hospitalization for six chronic ambulatory care sensitive conditions in the USA. *Ethn Health* 2006;11:247–63.

13 Basu J, Friedman B, Burstin H. Primary care, HMO enrollment, and hospitalization for ambulatory care sensitive conditions: a new approach. *Med Care* 2002;40:1260–9.

14 Parchman ML, Culler SD. Preventable hospitalizations in primary care shortage areas. An analysis of vulnerable Medicare beneficiaries. *Arch Fam Med* 1999;8:487–91.

15 Kozak LJ, Hall MJ, Owings MF. Trends in avoidable hospitalizations, 1980-1998. *Health Aff (Millwood)* 2001;20:225–32.

16 Magan P, Alberquilla A, Otero A, Ribera JM. Hospitalizations for ambulatory care sensitive conditions and quality of primary care: their relation with socioeconomic and health care variables in the Madrid regional health service (Spain). *Med Care* 2011;49:17–23.

17 Schiotz M, Price M, Frolich A, et al. Something is amiss in Denmark: a comparison of preventable hospitalisations and readmissions for chronic medical conditions in the Danish Healthcare system and Kaiser Permanente. *BMC Health Serv Res* 2011;11:347.

18 Bindman AB, Grumbach K, Osmond D, et al. Preventable hospitalizations and access to health care. *JAMA* 1995;274:305–11.

19 Hossain MM, Laditka JN. Using hospitalization for ambulatory care sensitive conditions to measure access to primary health care: an application of spatial structural equation modeling. *Int J Health Geogr* 2009;8:51.

20 Bindman AB, Goodwin K, Chattopadhyay A, Auerback G. *Preventable Hospitalizations among Medi-Cal Beneficiaries and the Uninsured*. Oakland, CA: California HealthCare Foundation, 2007.

21 Rosano A, Abo Loha C, Falvo R, et al. The relationship between avoidable hospitalization and accessibility to primary care: a systematic review. *Eur J Public Health* 2012; doi:10.1093/eurpub/cks053.

22 Baldwin LM, Dobie SA, Cai Y, et al. Receipt of general medical care by colorectal cancer patients: a longitudinal study. *J Am Board Fam Med* 2011;24:57–68.

23 Warren JL, Klabunde CN, Schrag D, et al. Overview of the SEER-Medicare data: content, research applications, and generalizability to the United States elderly population. *Med Care* 2002;40(Suppl. 8):IV–3–18.

24 National Cancer Institute. SEER-Medicare: About the Data Files. U.S. National Institutes of Health. Available at: http://healthservices.cancer.gov/seermedicare/aboutdata/ (2 November 2006, date last accessed).

25 National Cancer Institute. SEER Registries. U.S. National Institutes of Health. Availabe at http://seer.cancer.gov/registries/ (2 November 2006, date last accessed).

26 Saver BG, Dobie SA, Green PK, et al. No pain, but no gain? The disappearance of angina hospitalizations, 1992–1999. *Med Care* 2009;47:1106–10.

27 Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987;40:373–83.

28 Romano PS, Roos LL, Jollis JG. Adapting a clinical comorbidity index for use with ICD-9-CM administrative data: differing perspectives. *J Clin Epidemiol* 1993;46:1075–9.

29 Andersen RM. *A behavioral model of families' use of health services*. Chicago, IL: Center for Health Administration Studies, University of Chicago, 1968.

30 Andersen RM. Revisiting the behavioral model and access to medical care: does it matter? *J Health Soc Behav* 1995;36:1–10.

31 WWAMI Rural Health Research Center. Rural-Urban Commuting Area Codes (RUCAs). Version 1.11. 2005. Available at: http://depts.washington.edu/uwruca/ruca-data.php. (18 December 2006, date last accessed).

32 Bach PB, Guadagnoli E, Schrag D, et al. Patient demographic and socioeconomic characteristics in the SEER-Medicare database applications and limitations. *Med Care* 2002;40(Suppl. 8):IV–19–25.

33 Braunstein JB, Anderson GF, Gerstenblith G, et al. Noncardiac comorbidity increases preventable hospitalizations and mortality among medicare beneficiaries with chronic heart failure. *J Am Coll Cardiol* 2003;42:1226–33.

34 Niefeld MR, Braunstein JB, Wu AW, et al. Preventable hospitalization among elderly medicare beneficiaries with type 2 diabetes. *Diabetes care* 2003;26:1344–9.

35 Phelan EA, Borson S, Grothaus L, et al. Association of incident dementia with hospitalizations. *JAMA* 2012;307:165–72.

36 Wolff JL, Starfield B, Anderson G. Prevalence, expenditures, and complications of multiple chronic conditions in the elderly. *Arch Int Med* 2002;162:2269–76.

37 Laditka JN. Hazards of hospitalization for ambulatory care sensitive conditions among older women: evidence of greater risks for African Americans and Hispanics. *Med Care Res Rev* 2003;60:468–95.

38 Laditka JN, Laditka SB. Insurance status and access to primary health care:disparate outcomes for potentially preventable hospitalization. *J Health Soc Policy* 2004;19:81–100.

39 Stranges E, Stocks C. Potentially Preventable Hospitalizations for Acute and Chronic Conditions 2008. HCUP Statistical Brief #99. Agency for Healthcare Research and Quality. Available at: http://www.hcup-us.ahrq.gov/reports/statbriefs/sb99.pdf. (20 April 2010, date last accessed).

40 Agency for Healthcare Research and Quality. Quality Indicator User Guide: Prevention Quality Indicators (PQI) Composite Measures Version 4.3. Department of Health and Human Sevices, Agency for Healthcare Quality and Research, August 2011. Available at: http://www.qualityindicators.ahrq.gov/Downloads/Software/SAS/V43/Composite_User_Technical_Specification_PQI_4.3.pdf. (28 December 2011, last date accessed).