Using chronic disease risk factors to adjust Medicare capitation payments

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This study evaluates the use of risk factors for chronic disease as health status adjusters for Medicare's capitation formula, the average adjusted per capita costs (AAPCC). Risk factor data for the surviving members of the Framingham Study cohort who were examined in 1982-83 were merged with 100 percent Medicare payment data for 1984 and 1985, matching on Social Security number and sex. Seven different

AAPCC models were estimated to assess the independent contributions of risk factors and measures of prior utilization and disability in increasing the explanatory power of AAPCC. The findings suggest that inclusion of risk factors for chronic disease as health status adjusters can improve substantially the predictive accuracy of AAPCC.

Introduction

The capitation formula used by the Medicare program to pay health maintenance organizations (HMOs) for their elderly enrollees, called the average adjusted per capita cost (AAPCC), has little power to predict future health services expenditures. A great deal of research is under way to identify health status adjusters for AAPCC which would more accurately predict health care costs and thus, reduce financial risk for HMOs and the Federal Government. Excellent measures of prospective health or risk status which have received very little attention in health services research as potential health status adjusters for capitation payments are the major risk factors for chronic disease, such as cigarette smoking, systolic blood pressure, serum cholesterol, forced vital capacity, and blood glucose. The research conducted to determine the extent to which risk factors for chronic disease predict and explain variation in health care costs has been done only for non-elderly populations (Howland et al., 1987, Lubitz, 1987; Newhouse et al., 1989). As both Gruenberg et al. (1985) and McClure (1984) suggest, the advantage of risk factors is that they permit early identification of persons at high risk of utilization (Lubitz, 1987). This study evaluates the use of risk factors for chronic disease as measured in an elderly population as potential health status adjusters for the AAPCC.

Data and methods

Study population

The study population for this research is the surviving elderly population from the original cohort of the Framingham Study. The original cohort was selected in 1948 as a random sample of two-thirds of the approximately 10,000 persons 30-59 years of age residing in the town of Framingham, Massachusetts (Dawber, 1980). A large number of volunteers also were accepted for examination, and 734 were found to be eligible. The total study population in 1948 consisted of 5,209 persons (2,336 men and 2,873 women) ages 28-62.

All members of the original study cohort who met the following criteria qualified for inclusion in the sample population for this research.

- Survived to January 1, 1984.
- Were residents of Middlesex County, Massachusetts in 1984.
- Were examined in 1982-83 in exam 17 by the Framingham Study.
- Were 65 years of age or over by January 1, 1984.
- Were enrolled in Parts A and B of the Medicare program in 1984 and/or 1985.
- Were not HMO members during 1984 and 1985.

In 1982, the original cohort ranged from 62 to 93 years of age; thus, nearly all surviving persons who were examined in 1982 were potentially eligible to be included in the sample. A total of 2,086 persons were examined by Framingham physicians in exam 17. These exams took place during a 2-year period, from 1982 through 1983. The date of the exam was included in all analytic models to control for the differential length of time between the exam and Medicare payments. However, the date of exam was not statistically significantly associated (range of p-values $= 0.16 - 0.75$) with subsequent Medicare payments in any of the models.

Because the analysis extends over several years, it was expected that many individuals would die during the study period. Only those individuals who were alive for 1 or more days in a study year were included in equations for that year.

Of the 2,086 persons who participated in exam 17, 30 percent or 625 were not eligible for inclusion in the study for the following reasons:

- 3 percent or 69 persons were not 65 years of age by January 1, 1984.
- 3 percent or 69 persons died before January 1, 1984.
- One person was not eligible for Medicare Parts A or B in 1984 or 1985.
- 19 percent or 392 persons had moved out of Middlesex County, and thus, Medicare data were not available for 1984 or 1985.
- 5 percent or 94 persons had no Social Security number recorded by the study and thus, their risk factor data could not be matched to Medicare payments.

Linking Framingham and Medicare files

Each record from the study was matched to the Medicare 1984 and 1985 enrollment tapes using the Social Security number, sex, and date of birth. The beneficiary identification codes (BIC) were checked manually to verify the match. If the BIC did not match, often this reflected only that the basis for Medicare entitlement had changed. A list of compatible BICs provided by the Health Care Financing Administration (HCFA) was used to determine if the Medicare record was a true match or represented a different beneficiary. Of the 1,461 participants in the study who met the eligibility criteria defined previously, 14 percent could not be matched to the Medicare enrollment tape. The reasons for these non-matches are unknown, but may include recording errors for Social Security numbers in the Framingham data, errors on the Medicare enrollment tape, and persons ineligible for Medicare, such as railroad retirees and their dependents. The final matched sample included 1,162 persons (522 men and 640 women) who met all the eligibility requirements. For each Medicare beneficiary matched on the enrollment tape, the health insurance claim number and sex were used to match records on the payment tapes.

An analysis of the differences between the matched sample of 1,162 persons with the 786 remaining unmatched cohort (who were eligible based on their age and survival to January 1984, but not included in the matched sample because either they had moved out of Middlesex County, had no Social Security number recorded in Framingham records, or they failed to match because of recording errors in the Framingham or Medicare tapes) shows no differences expected to bias the results, although some of the differences are statistically significant ($p < .05$). The matched sample had more men, was less than 1 year older (72.6 years versus 71.5), had a lower cholesterol level (both were elevated, with a mean of 229 mg/dl for the matched sample and 233 mg/dl for the non-matched), had a greater average number of pack years (18.6 versus 17.2), and had a higher average 2-year probability of cardiovascular disease (.076 versus .064). Comparisons of mean values for number of cigarettes smoked per day, systolic blood pressure, blood sugar, forced vital capacity, prior hospitalization, prior use of physician

services, and disability level were not statistically significantly different for the matched and non-matched samples.

Dependent variables

Data on 100 percent Medicare Part A and B payments for 1984 and 1985 for all beneficiaries residing in Middlesex County were made available by HCFA. All procedures for handling these data conformed to protocols for confidentiality established by the Framingham Study and HCFA. It is important to note that the prospective payment system (PPS) using diagnosis-related groups (DRGs) was not implemented in Massachusetts until 1986, so that the payments used in this study represent Medicare payments on actual charges for services rendered.

Medicare Part A and B payments were summed for each individual in the study sample for 1984 and 1985 to calculate total annual Medicare payments per beneficiary. Total payments per person per year were then weighted to reflect the period of time each study individual was alive during each study year (Ash et al., 1989). Data on date of death during 1984 and 1985 were obtained from exams 18 (1984-85) and 19 (1986-87) of the Framingham Study. For each person who died during 1984 or 1985, their total annual Medicare payments were weighted by the proportion of 365 days of each year they were alive. This method of weighting payment data adjusts for mortality in the elderly population and takes into account the extraordinarily high costs of beneficiaries in their final months of life. One dollar was added to total weighted payments prior to logging them. Log transformations of total weighted payments per person per year were then made to correct for the highly skewed distribution of payments, and were entered as continuous variables [$Y = \ln(\text{weighted}(\$Part A + \$Part B) + \$1))$]. Univariate statistics for the dependent variable are presented in Table 1.

Independent variables

Data were available on 13 independent variables. Data on three AAPCC variables (age, sex, and institutional status), seven risk factors (systolic blood pressure, serum cholesterol, cigarettes per day, pack years, forced vital capacity, blood sugar, and 2-year probability of cardiovascular disease), two measures of prior utilization (prior hospitalization and prior physician visits in the past 2 years), and disability level were obtained from the 1982-83 examination (exam 17) of the Framingham Study. The independent variables, their measures, means, maximums, and standard deviations are presented in Table 1.

Capitation rate variables

The present AAPCC formula is based on age, sex, institutional status, welfare status, and geographic location. AAPCC was estimated for this research using age, sex, and institutional status as reported in exam 17 of the Framingham Study. Data on welfare status were

Table 1

Descriptive statistics for independent and dependent variables

Variable	Measures	Mean	Maximum	Standard deviation
AAPCC				
Age	Years at exam 17 (1982-83)	72.56	92	6.75
Sex	Male = 0, Female = 1	0.55	1	0.49
Institutional status	1 = Nursing home; institution	0.029	1	0.17
	0 = Private residence			
Disability				
Disability level	Index (1-8)	2.10	8	1.39
Prior use				
Prior hospitalization	In past 2 years = 1, none = 0	0.28	1	.45
Prior physician visits	In past 2 years = 1, none = 0	0.74	1	.44
Risk factors				
Cigarettes per day	Cigarettes smoked per day	2.39	50	6.97
Pack years	Packs per day summed over total			
	number of years smoked	17.61	99	23.13
Systolic	Dichotomous (0,1)	0.22	1	0.41
Blood pressure	Treatment level	2.72	72	7.81
	(Sys BP-160 mmHg)			
	Total (mmHg)	143.52	232.00	20.38
Serum cholesterol	mg/dl	228.72	388	40.90
Blood sugar	mg/dl	94.69	370	32.99
Forced vital capacity	(cl/inch)	267.59	609	78.87
2-year probability of				
cardiovascular disease	Probability	0.08	0.55	0.06
Medicare payments				
Total 1984 Medicare	Unweighted dollars	$2,235.22	$64,303.31	169.63
Payments[1]	Log of weighted dollars	4.58	14.90	3.40
Total 1985 Medicare	Unweighted dollars	$2,786.43	$60,768.67	197.03
Payments[1]	Log of weighted dollars	5.39	12.64	3.05

[1]Reported as total Medicare payments per beneficiary based on the sum of Part A and Part B dollar payments.

NOTES: AAPCC is average adjusted per capita cost. mg/dl is milligrams per deciliter. mmHg is millimeters of mercury. cl/inch is centiliters per inch.

SOURCE: The Framingham Study, Boston University; Health Care Financing Administration: Data from the Medicare Automated Data Retrieval System.

missing on the Medicare data tape used for this study, but welfare status has not been shown to be a good predictor for the AAPCC since conditions for entitlement vary widely from State to State. Also, welfare status in the current AAPCC does not distinguish between those who are medically needy versus those who are entitled by income level. Geographic location was controlled by restriction, as all members of the study population lived in Middlesex County.

Chronic disease risk factors

Epidemiological evidence of the relationships between specific risk factors and chronic disease morbidity and mortality in the elderly is the basis for selecting the chronic disease risk factors under study. All risk factor data were obtained from exam 17 of the Framingham Study, with the exception of serum cholesterol level. Blood cholesterol levels were obtained from exam 15 of the study, as they were not measured in exams 16 or 17.

All risk factor variables with the exception of systolic blood pressure were entered using continuous values. Systolic blood pressure was measured in two ways to take into account treatment effects (Newhouse et al., 1989). A measure of elevated systolic blood pressure was estimated using a dichotomous variable defined as

systolic blood pressure greater than 160 mmHg. The treatment level was measured as a continuous variable equal to systolic blood pressure minus 160 for systolic pressures greater than or equal to 160 mmHg, and 0 for systolic pressures less than 160 mmHg. The cutoff point of 160 mmHg reflects the judgment of Framingham physicians about the value below which most physicians would not treat hypertension in the elderly.

An aggregate measure of risk also was computed for each individual, using the coefficients from the Framingham Study which predict the logistic function for an individual's 2-year probability of cardiovascular disease. The variables which make up this index include age, sex, systolic blood pressure level, serum cholesterol level, a dichotomous measure of glucose intolerance, left ventricular hypertrophy, a dichotomous smoking status variable, the interaction of gender and glucose intolerance status, and the interaction of age and cholesterol. The index represents the probability that an individual will get cardiovascular disease within the next 2 years.

In addition to present risk status, prior risk status also may influence health care utilization and costs. The extent to which present status is independent of prior status probably varies by risk factor. Data on prior risk status were not available for this study with the exception of cigarette smoking. Because the long-term

effects of smoking are so serious and are associated with different health outcomes than present smoking status, a measure of pack years of smoking was included in the analysis. Pack years is calculated based on the sum of the number of packs a day a person smoked times the number of years of smoking at that level, over the person's lifetime. Thus, if someone smoked two packs of cigarettes a day for 10 years their pack years would equal 20. For risk factors other than smoking, it is important to take into consideration the possible effects of a life-long pattern of risk status in interpreting the findings.

Finally, interactions between sex and cigarettes per day, and age and cigarettes per day were created based on the epidemiologic literature (Centers for Disease Control, 1987).

Prior use variables

Dummy variables were created for the prior use variables obtained from exam 17 (1982-83) of the study, indicating whether or not each person had been hospitalized in the past 2 years and had visited a physician in the past 2 years.

Disability index

Disability level was measured using a disability index from exam 17 of the Framingham Study that ranged in values from 1 (free of disability) to 8 (severely disabled). The index is an ordinal variable with its values representing increasing levels of disability and poor functional status based on each person's response to 18 questions on physical functioning. These questions include a modified selection of Katz's activities of daily living (ADL) (Katz et al., 1970), Branch's additions to the ADL scale (Branch et al., 1984), a portion of the Rosow and Breslau's Functional Health Scale measuring gross mobility (Rosow and Breslau, 1966), and selected measures of physical performance adopted from Nagi's work on disability (Nagi, 1976). Each of these items had been used and validated in the Framingham Disability Study (Jette and Branch, 1981).

Testing models

The analysis evaluates variations of the AAPCC capitation formula used by Medicare to prospectively pay HMOs for elderly beneficiaries. Seven different models were evaluated to assess the influence of various combinations of variables in explaining variation in subsequent Medicare payments.

Three sets of variables were added to the basic AAPCC in different combinations to create five additional models, and one model was based exclusively on chronic disease risk factors. Least-squares regression analysis was used to estimate the seven AAPCC models for 1984 and 1985 logged weighted total Medicare payments for the full sample and by sex. The seven models are:

Model 1: AAPCC (age, sex, institutional status).
Model 2: AAPCC + prior use (prior hospitalization, prior doctor visits).

Model 3: AAPCC + disability (disability level).
Model 4: AAPCC + risk factors (blood pressure, serum cholesterol, blood sugar, 2-year probability of cardiovascular disease, forced vital capacity, cigarettes per day, pack years).
Model 5: AAPCC + prior use + risk factors.
Model 6: AAPCC + prior use + risk factors + disability.
Model 7: Risk factors only.

Measures of goodness of fit

The performance of the models in predicting future costs is evaluated using several different measures of the model's goodness of fit. The following describes each of the methods used in the models.

The first measure was estimated using R^2s and adjusted R^2s, adjusting the R^2 value for the number of parameters in each model. Regression coefficients and standardized beta coefficients were estimated for all variables in each of the models, and statistical significance of all variables was calculated.

Due to missing values in the data, the sample sizes and thus the data sets used to estimate each model differ. To test whether the reported R^2s are an artifact of the different data sets, we also re-estimated the seven models for 1984 and 1985 payments and recalculated the R^2s and adjusted R^2s on the most restricted data sets, selecting only those cases used in Model 6, where data used in all models are available.

The R^2s measure how well a model predicts Medicare payments at the individual beneficiary level. However, the AAPCC must be able to make accurate predictions for a group of elderly beneficiaries. Although the present AAPCC can make good predictions on a large group of randomly selected Medicare beneficiaries, it performs less well on subgroups of the population with health histories which deviate from the average. Using a method developed by Ash et al. (1989), measures of prediction bias, called predictive ratios (PRs), were produced to assess how well each model predicts the average 1984 and 1985 payments for three defined subgroups. The subgroups were selected based on demographic characteristics and atypical health status or prior health services utilization (Ash et al., 1989). The PR for a specific subgroup and model is defined as:

$$PR = \frac{\text{Average of the model's predictions}}{\text{Average of actual payments}}$$

The best models have PRs close to 1 across several subgroups. A PR greater than 1 indicates that a model will lead to overpayment for a group; a PR less than 1 indicates that a model will lead to underpayment for a group (Ash et al., 1989). The four subgroups are defined as follows:

65YRF   Women 65-69 years ($N = 201$).
NOUSE   Men and women over age 65 who reported no prior utilization at exam 17 (both prior hospitalization and prior doctor visits = 0) ($N = 232$).

PRIORHOSP   Men and women over age 65 who
            reported at exam 17 of being
            hospitalized at least once in the past
            2 years (N = 306).
CVDPROB   Men and women over age 65 whose
            2-year probability of cardiovascular
            disease at exam 17 was greater than
            10 percent (N = 269).

The PRs were compared across the four subgroups for
each of the seven models estimated for 1984 and 1985
logged weighted payments.

Finally, the findings were cross-validated to see how
well predictions made using models fit to the 1984 data
fit the actual 1985 data. Each of the seven models was
evaluated on the basis of how well the predicted 1984
payments fit the actual 1985 costs for the study sample
by estimating an R^2 equal to sum of squares error (SSE)
over total sum of squares (TSS), where SSE = (actual
85 − predicted 84)^2, and TSS = (actual 85 − mean
85)^2. Using this methodology, R-squared values will be
negative whenever SSE is greater than TSS, and R^2
would reach its maximum value of 1.00 only when
predicted and actual costs were identical for every
beneficiary (Ash et al., 1989).

To summarize, we have six different measures of
performance for each of the models: R^2s estimated on
logged weighted payments for the full sample, PR for
four subgroups of the population, and cross-validated
1985 R^2s estimated using 1984 predicted costs. In
addition, the sensitivity of the findings is assessed by
examining the relative ranking of the R^2s across the
seven models estimated on logged weighted payments
only for cases with complete records on all variables
used in all models.

Results

The results for the regression analyses on the seven
AAPCC models for 1984 and 1985 logged weighted
Medicare payments for the full sample are presented in
Tables 2-4. Table 2 presents the adjusted R^2s for all
seven models for total logged weighted Medicare
payments for the full sample and by sex for 1984 and
1985. Tables 3 and 4 present the standardized beta
coefficients for all seven models for the full sample for
1984 and 1985, respectively. All seven models for the

full sample for 1984 and 1985 logged weighted Medicare
payments were statistically significant at the $p < 0.0001$
level. All seven models by sex were statistically
significant at the $p < .05$ level.

Capitation model

The AAPCC model (Model 1) explained between
2-3 percent of the variance in subsequent total Medicare
payments during a 2-year period, with adjusted-R^2 of
2.7 and 2.5 percent for 1984 and 1985, respectively. The
explanatory power of the AAPCC model decreases
during the 2-year time period for women, and increases
during the time period for men. The only variable which
achieves statistical significance in the AAPCC model is
age. Age retains its statistical significance with the
addition of prior use variables (Model 2) and the
disability index (Model 3), but is not statistically
significant in any of the models which include the
chronic disease risk factors (Tables 3 and 4).

Prior utilization model

The measures of prior utilization to AAPCC
(Model 2) increase the explanatory power of the model
more than two to three times. As shown in Table 2, the
addition of the prior utilization variables to AAPCC
for the full sample increases the adjusted-R^2s to
6.0 and 7.7 percent for 1984 and 1985, respectively.
Both measures of prior utilization, prior hospitalization
and physician visits, are positively and statistically
significantly associated ($p < .001$) with subsequent total
Medicare payments during 1984 and 1985 (Tables 3 and
4). The prior use variables retain their statistical
significance in all AAPCC model variations examined.

Disability index model

The addition of the disability index to AAPCC
(Model 3) increases the explanatory power of the model
more than two times. As shown in Table 2, the addition
of the disability index to AAPCC for the full sample
increases the adjusted-R^2s to 6.7 and 4.8 percent for
1984 and 1985, respectively. The predictive power of the
disability index decreases substantially during 2 years
for women and increases slightly for men (Table 2). The

Table 2
Summary of adjusted-R^2s by percent for AAPCC Models 1-7, by sex[1]: 1984 and 1985

Model	Description	Full sample		Men		Women	
		1984	1985	1984	1985	1984	1985
		Percent					
Model 1	AAPCC	2.7	2.5	1.7	2.4	3.6	2.4
Model 2	AAPCC + prior use	6.0	7.7	4.9	7.5	7.6	7.6
Model 3	AAPCC + disability	6.7	4.8	7.6	8.0	6.1	2.7
Model 4	AAPCC + risk factors	4.9	6.6	5.2	2.8	5.2	9.1
Model 5	Model 2 + risk factors	8.0	10.8	7.8	8.7	8.8	11.8
Model 6	Model 5 + disability	9.8	13.0	8.6	11.3	11.0	13.2
Model 7	Risk factors only	5.0	6.5	5.5	3.0	5.3	8.9

[1]Results are based on least-squares regression analysis on logged weighted Medicare payments.

NOTE: AAPCC is average adjusted per capita cost.

SOURCE: The Framingham Study, Boston University; Health Care Financing Administration: Data from the Medicare Automated Data Retrieval System.

Table 3
Summary of regressions on logged weighted Medicare payments: 1984

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
				Coefficient			
Age	[1]0.1585	[1]0.1336	[1]0.0923	0.0629	0.0488	0.0325	—
Sex	−0.0114	0.0001	−0.0079	0.0063	0.0176	0.0179	—
Institutional status	0.0419	0.0360	−0.0211	0.0160	0.0151	0.0179	—
Prior hospitalization	—	[1]0.1699	—	—	[1]0.1390	[1]0.1115	—
Prior physician visit	—	[2]0.0621	—	—	[1]0.0963	[1]0.1077	—
Disability	—	—	[1]0.2250	—	—	[1]0.1388	—
Dichotomous systolic BP	—	—	—	0.0076	0.0194	0.0546	0.0070
Systolic BP treatment level	—	—	—	−[3]0.0844	−[2]0.1027	−[2]0.1162	−[3]0.0898
Forced vital capacity	—	—	—	−[1]0.1331	−[1]0.1259	−[2]0.0947	−[1]0.1592
Serum cholesterol	—	—	—	−0.0076	−0.0046	−0.0085	−0.0095
Blood sugar	—	—	—	[1]0.1038	[1]0.0968	[1]0.1022	[1]0.0995
2-year CVD probability	—	—	—	[2]0.1106	[3]0.1078	0.0753	[1]0.1460
Cigarettes per day	—	—	—	[3]0.2241	[2]0.2855	[2]0.3037	0.1987
Pack years	—	—	—	[2]0.1062	[2]0.1036	[1]0.1101	[2]0.0962
Sex X cigarettes per day	—	—	—	−[3]0.1683	−[3]0.1967	−[3]0.1938	−[3]0.1653
Age X cigarettes per day	—	—	—	−[2]0.1679	−[2]0.1892	−[2]0.2051	−[2]0.1501
R^2 (percent)	2.9	6.4	7.1	6.4	9.6	11.6	6.1
Adjusted R^2 (percent)	2.7	6.0	6.7	4.9	8.0	9.8	5.0
Degrees of freedom	1,116	1,078	1,042	866	840	794	867
F value	11.2	14.7	19.8	4.5	5.9	6.4	5.6
Prob>f	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

[1]The p-value for the standardized beta coefficient is <0.01.
[2]The p-value for the standardized beta coefficient is <0.05.
[3]The p-value for the standardized beta coefficient is <0.10.

NOTES: BP is blood pressure. CVD is cardiovascular disease.

SOURCE: The Framingham Study, Boston University; Health Care Financing Administration: Data from the Medicare Automated Data Retrieval System.

Table 4
Summary of regressions on logged weighted Medicare payments: 1985

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
				Coefficient			
Age	[1]0.1655	[1]0.1465	[1]0.1084	0.0467	0.0261	0.0240	—
Sex	−0.0466	−0.0306	−0.0363	0.0208	0.0506	0.0589	—
Institutional status	−0.0166	−0.0414	−0.0534	0.0533	0.0521	0.0567	—
Prior hospitalization	—	[1]0.2021	—	—	[1]0.1614	[1]0.1365	—
Prior physician visit	—	[1]0.0857	—	—	[1]0.1074	[1]0.1319	—
Disability	—	—	[1]0.1788	—	—	[1]0.1424	—
Dichotomous systolic BP	—	—	—	0.0246	0.0546	[3]0.0810	0.0207
Systolic BP treatment level	—	—	—	−0.0757	−[2]0.1098	−[2]0.1152	−0.0756
Forced vital capacity	—	—	—	−0.0701	−0.0643	−0.0647	−[1]0.0992
Serum cholesterol	—	—	—	−[2]0.0848	−[2]0.0832	−[1]0.0977	[2]0.0831
Blood sugar	—	—	—	0.0549	0.0355	0.0319	0.0526
2-year CVD probability	—	—	—	[1]0.1684	[1]0.1755	[1]0.1514	[3]0.1833
Cigarettes per day	—	—	—	0.0219	0.0520	0.0862	0.0454
Pack years	—	—	—	0.0637	0.0737	[2]0.0848	0.0500
Sex X cigarettes per day	—	—	—	−[3]0.1929	−[2]0.2342	−[2]0.2750	−0.1786
Age X cigarettes per day	—	—	—	0.0380	0.0075	0.0122	0.0490
R^2 (percent)	2.8	8.1	5.2	8.1	12.5	14.8	7.7
Adjusted R^2 (percent)	2.5	7.7	4.8	6.6	10.8	13.0	6.5
Degrees of freedom	1,053	1,019	982	829	804	760	830
F value	9.99	17.95	13.45	3.93	7.49	8.07	6.80
Prob>f	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

[1]The p-value for the standardized beta coefficient is <0.01.
[2]The p-value for the standardized beta coefficient is <0.05.
[3]The p-value for the standardized beta coefficient is <0.10.

NOTES: BP is blood pressure. CVD is cardiovascular disease.

SOURCE: The Framingham Study, Boston University; Health Care Financing Administration: Data from the Medicare Automated Data Retrieval System.

disability index is positively and statistically significantly associated ($p < .001$) with subsequent total Medicare payments during 1984 and 1985 and it retains its statistical significance in all of the AAPCC model variations examined (Tables 3 and 4).

Chronic disease risk factor model

The use of chronic disease risk factors to adjust AAPCC (Model 4) increases the explanatory power of AAPCC two to three times for the full sample, with adjusted-R^2s of 4.9 and 6.6 percent for 1984 and 1985, respectively. The chronic disease risk factors which are statistically significant ($p < .05$) in Model 4 for the full sample in 1984 and/or 1985 include the 2-year probability of cardiovascular disease, cigarettes smoked per day, pack years, systolic blood pressure treatment level, serum cholesterol, blood sugar, and forced vital capacity.

The chronic disease risk factors alone explain 5.0 to 6.5 percent (adjusted-R^2s) of the variation in Medicare payments (Model 7). In most cases, the risk factors retain their statistical significance in the other AAPCC model variations (Models 4-6). Exceptions include the increasing statistical significance of systolic blood pressure treatment level with the addition of the prior utilization variables, the reduced statistical significance of forced vital capacity, and the increased statistical significance of pack years when the model is adjusted for disability. In addition, the 2-year probability of cardiovascular disease loses its statistical significance in the 1984 models explaining variation in Medicare payments 1 year following the risk assessment at exam 17 of the study. However, the 2-year probability of cardiovascular disease is highly significant ($p < .01$) in all models 2 years following the risk assessment for 1985 Medicare payments.

The impact of chronic disease risk factors on the explanatory power of the AAPCC model differs substantially by sex (Table 2). For men, the addition of the risk factors increases the adjusted-R^2 of Model 4 from 1.7 to 5.2 percent in 1984, but only slightly increases the explanatory power of the model in 1985 from an adjusted-R^2 of 2.4 to 2.8 percent. In fact, none of the chronic disease risk factors achieves statistical significance ($p < .05$) for men in Model 4 in 1985. Limitations in the power of the model because of the small number of men in the sample (approximately 330 with complete records) may explain the inability to detect statistically significant contributions of risk factors for men. For women in 1984, the addition of the chronic disease risk factors (Model 4) to AAPCC increases the adjusted-R^2 from 3.6 to 5.2 percent. More important, the addition of chronic disease risk factors to the AAPCC model for women in 1985 increases the adjusted-R^2 from 2.4 to 11.8 percent.

Multiple adjustment models

The addition of both prior use and chronic disease risk factors (Model 5) improves the explanatory power of the models even further, increasing the explained

variance of AAPCC by a factor of three to four times for the full sample. The adjusted-R^2s for Model 5 for the full sample are 8.0 and 10.8 percent for 1984 and 1985, respectively.

The best models are those which incorporate all three health status adjusters: prior use, disability level, and chronic disease risk factors. The adjusted-R^2s for Model 6 for the full sample are 9.8 and 13.0 percent in 1984 and 1985, respectively. Models 5 and 6 consistently explain more variation in payments for women than men and more variation for 1985 payments compared with 1984. The model with the strongest explanatory power was Model 6 for 1985 Medicare payments for women, yielding an adjusted-R^2 of 13.2 percent.

Predictive power

Table 5 presents the results for the cross validation analysis and the PRs. The cross-validated R^2s evaluate how well the predicted 1984 payments, estimated from models fit to the 1984 data, fit the 1985 cost data. The cross-validating R^2 for all seven models is much smaller than its conventional 1984 R^2, with most of the cross-validating R^2s taking on negative values. However, the relative rankings of the models by these two measures are similar. The cross-validated R^2 for the unadjusted AAPCC (Model 1) is the least predictive of the models. The most notable difference in the relative ranking of the cross-validated R^2 compared with the 1984 R^2 is the better ability of the prior use model (Model 2) to predict 1985 costs (-0.3 percent). However, Model 6 remains the best predictive model tested, with a 1984 R^2 of 11.6 percent and the only positive cross-validated 1985 R^2 of 0.6 percent.

All of the models produce PRs near one for the subgroup of females 65-69 years (65YRF), with a range of 0.99 to 1.05. The current AAPCC formula underpays the subgroup with at least one prior hospitalization (PRIORHOSP), and overpays the group with no prior health services utilization (NOUSE). The AAPCC models adjusted only for disability (Model 3) and for risk factors (Model 4) underpay (PRs from 0.84 - 0.87) for persons with prior hospitalization and overpay (PRs from 1.18 - 1.30) for persons with no prior utilization. Model 5 which adjusts AAPCC for both prior use and risk factors produces PRs much closer to 1, with PRs ranging from 1.00 to 1.02 for 1985 payments. The best models across all subgroups are the AAPCC adjusted only for prior use (Model 2) and the AAPCC adjusted for prior use, disability, and chronic disease risk factors (Model 6). Taking into consideration both the cross-validating R^2s and the PRs, we conclude that Model 2 (prior use) and Model 6 (prior use, disability, and risk factors) have the most power to predict future expenditure across groups and over time compared with all of the other models tested in this research.

Sensitivity of findings

The sensitivity of findings to variations in sample size across the models due to missing data are presented in Table 6. All models were re-estimated on uniform

Table 5
Cross-validated R^2s and predictive ratios of Models 1-7: 1984 and 1985

Model and year	1984 R^2 and cross-validated 1985 R^2	Predictive ratio			
		65YRF	NOUSE	PRIORHOSP	CVDPROB
Model 1	Percent				
1984	2.9	0.99	0.83	1.22	0.99
1985	−4.9	1.01	0.83	1.17	0.99
Model 2					
1984	6.4	1.00	1.00	1.03	1.00
1985	−0.3	1.01	1.00	0.99	0.99
Model 3					
1984	7.1	1.00	0.87	1.21	0.99
1985	−3.1	1.00	0.86	1.18	0.99
Model 4					
1984	6.4	1.03	0.84	1.30	1.03
1985	−3.2	1.02	0.86	1.20	1.00
Model 5					
1984	9.6	1.03	1.00	1.05	1.03
1985	−0.9	1.02	1.00	1.01	1.01
Model 6					
1984	11.6	1.03	1.00	1.04	1.02
1985	0.6	1.01	1.00	1.00	1.00
Model 7					
1984	6.1	1.05	0.84	1.30	1.02
1985	−3.9	1.03	0.86	1.20	1.00

NOTES: AAPCC is adjusted average per capita cost. The variables are defined in Table 1. Models are defined in Table 2.

SOURCE: The Framingham Study, Boston University; Health Care Financing Administration: Data from the Medicare Automated Data Retrieval System.

Table 6
Sensitivity of model rankings to sample size: 1984 and 1985

Variable versus fixed sample sizes	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Variable sample sizes							
1984:							
R^2-percent	2.7	6.0	7.1	6.4	9.6	9.8	6.1
Sample size	(1,117)	(1,079)	(1,043)	(867)	(841)	(795)	(868)
1985:							
R^2-percent	2.5	7.7	4.8	6.6	10.8	13.0	6.5
Sample size	(1,054)	(1,020)	(983)	(830)	(805)	(761)	(831)
Fixed sample size							
1984:							
R^2 − percent ($N = 795$)	1.2	4.4	4.5	5.4	8.3	9.8	5.6
1985:							
R^2 − percent ($N = 761$)	2.5	7.2	5.7	7.1	11.4	13.0	7.1

NOTES: Models are defined in Table 2. All R^2s are adjusted.

SOURCE: The Framingham Study, Boston University; Health Care Financing Administration: Data from the Medicare Automated Data Retrieval System.

data sets restricted to only those cases with complete records for all variables used in all models (uniform restricted sample sizes are 841 for 1984 payments, and 805 for 1985 payments). The findings exhibit the same pattern observed previously in terms of relative predictive power of AAPCC and its variations. The adjusted R^2 is smallest for the unadjusted AAPCC (Model 1). The addition of prior use, disability, or risk factor variables (Models 2-4) each substantially increases the explanatory power of the models by a factor of two to three times. The model with the highest R^2 is adjusted with all three measures of health status (Model 6). Thus, the sensitivity analysis confirms the importance and independent contribution of the risk factors in explaining variation in subsequent Medicare payments. The findings also suggest that the analyses of the AAPCC model variations on the variable sample sizes may understate the relative contribution of risk

factor variables, as exhibited by the relative rank of the adjusted R^2s for Model 4 (risk factor adjusted) compared with Model 2 (prior use) and Model 3 (disability).

Discussion

These findings not only confirm the previously demonstrated relationships of prior utilization and disability with Medicare payments, but they demonstrate, for the first time, a strong and independent association of risk factors for chronic disease and subsequent total Medicare payments during a 2-year period for the elderly population. Risk factors alone explained 5-6 percent of the variation in Medicare payments for elderly enrollees. The unadjusted AAPCC (Model 1) explained only 1-3 percent of the variation in Medicare payment, a finding which is comparable to adjusted-R^2s of approximately 1 to 2 percent for the AAPCC reported in the health services research literature (Ash et al., 1989; Gruenberg and Stuart, 1982).

The findings on the importance and independent contribution of prior utilization variables in explaining Medicare payments confirm those of Anderson and Knickman (1984), Roos and Shapiro (1981), Ash et al. (1989), Newhouse et al. (1989), and Anderson, Resnick, and Gertman, 1983), that prior utilization substantially improves the explanatory power of AAPCC. This research also confirms the importance of functional status in explaining variation in subsequent Medicare payments for elderly beneficiaries (Thomas et al., 1983; Thomas and Lichtenstein, 1986; Branch et al., 1984).

These findings suggest that each of the potential adjusters to AAPCC—prior use, disability, and chronic disease risk—is measuring a different aspect of health status which independently contributes to a greater understanding of health services utilization and expenditures for elderly Medicare beneficiaries.

Limitations of the study

The AAPCC models evaluated in this study are based on data available for non-HMO enrollees, and thus, the applicability of the findings to Medicare HMO enrollees in unknown. In addition, the surviving Framingham study cohort is not representative of the entire Medicare beneficiary population, and applicability to minority, low-income persons is unknown. Most important, the study sample is very small (1,162) compared with other AAPCC research which has been based on study populations of 20,000 or more Medicare beneficiaries.

The study population also differs from the general population simply because its members participate in a biannual exam that comprehensively monitors risk status. Although the examination itself does not involve any intervention, and the study has been extremely careful not to allow any intervention targeted specifically to the study population, the results of each examination performed as part of the study are forwarded to each participant's personal physician.

Thus, the physicians serving the study population may be alerted to elevated risks much earlier than they might be otherwise. As a result, participation in the study may accelerate the rate at which a link between high risk and higher outpatient utilization is made. The relationships, therefore, between risk factors and Part B Medicare payments may be stronger than that observed in the general population.

It is important to note that the personal physicians serving the study population are not part of the study, have received no specific training in risk reduction, and in general, are not suspected of behaving any differently than other physicians practicing medicine in Middlesex County. The Framingham Study provides no guidance to the personal physicians of study participants on how they should use or interpret information from the study, and these physicians operate under the same incentives and standards as other physicians practicing in Massachusetts. There is no evidence available to suggest that the practice patterns of the personal physicians of the study participants have been affected by the conduct of the study. Payment data for the Framingham Study participants do not suggest any differences from those of Medicare beneficiaries nationally.

Threats to the internal validity of this study are due primarily to classification errors. This is potentially most serious for the chronic disease risk factors which are subject to treatment through medication (Newhouse et al., 1989). For example, a person may have high blood pressure which is under control or below 160/90. This person is considered low risk, and yet medical expenditures to maintain control are expected to be much higher for this person than for the person whose blood pressure is naturally low. Although uncontrolled values are probably the more valid measures for explaining medical care costs, they cannot be observed. To the extent that future expenditures are lower for persons with hypertension which is under control compared with persons with hypertension that is not under control, the classification error should not present a serious problem. However, to the extent persons with hypertension that is under control have greater medical expenditures than persons with naturally occurring low blood pressure, classification bias exists. We have attempted to control for this bias by including both a dichotomous variable for being in treatment and a continuous variable measuring the variable costs associated with increased severity.

A final limitation of the study is the measure of prior utilization used. The two measures of prior use examined in this study were gathered from self-reports obtained during exam 17 of the study, which indicated whether or not each person had been hospitalized and had any physician visits in the past 2 years. These measures are more aggregate than the measures of prior utilization currently being considered for use in AAPCC, such as diagnostic cost groups which classify different types of prior hospitalization based on diagnoses. Therefore, it is still not known how much additional explanatory power chronic disease risk factors offer beyond these more precise definitions of prior health services utilization.

Conclusions and policy implications

We conclude that risk factors for chronic disease, which include both physiologic and behavioral measures of risk status, have the potential to substantially improve the explanatory power of the AAPCC formula, explaining a significant amount of variation in total Medicare payments during a 2-year period for elderly beneficiaries 65-93 years of age, controlling for measures of prior utilization and disability.

The previously stated findings support the hypothesis that it is measures of health status which are the primary determinants of health services utilization and total Medicare payments for the elderly. In comparison, the demographic variables, which presently serve as the basis for capitation payments to HMOs, contribute little to our understanding of health services utilization.

These findings suggest that a health status adjustment to AAPCC should incorporate several different measures of health status. Ouslander and Beck (1982) concur that a measure of health status should be comprehensive to include many domains, as measures in only one domain may not reflect overall health status or need for health services. To the extent that data are available, measures of prior and current health status, as well as measures of future health or risk status, should be included in the development of a health status adjuster to AAPCC.

The addition of risk factors for chronic disease improves the AAPCC models and more accurately explains variation in Medicare payments. Thus, chronic disease risk factors meet a statistical criterion of predictive accuracy. However, consideration of other criteria suggests that use of chronic disease risk factors as a health status adjuster for AAPCC has serious drawbacks, as do all other adjusters proposed to date. In evaluating alternative health status measures for developing a health status adjuster for AAPCC, a number of different criteria must be considered beyond predictive accuracy (Thomas et al., 1983; McClure, 1984; Ash et al., 1989). These include:

- How reliable the measure is.
- How reflective the measure is for risk of chronic disease, as opposed to acute illness.
- How applicable the use of the measure is to the entire Medicare enrolled population.
- What effect use of the measure will have on maintaining proper provider incentives in caring for older persons.
- How subject the measure is to manipulation by enrollees or providers.
- How feasible it is to collect data and administer the use of the measure.
- How acceptable the measure is ethically and politically.

The major advantages of using chronic disease risk factors as a health status adjuster for AAPCC are their predictive accuracy and their strong association with chronic disease. By definition, these risk factors reflect risk for chronic rather than acute disease, although they are also predictive of acute episodes of chronic disease,

such as myocardial infarction and stroke. Another advantage of chronic disease risk factors is that they can be objectively measured and verified, reducing concerns of manipulation in reporting risk levels and misclassification of risk status. Many of the risk factors for chronic disease are physiologic measures subject to direct verification, including blood pressure, glucose, cholesterol, forced vital capacity, height and weight. In addition, several physiologic measures are available to verify the status of those risk factors which are self-reported behaviors. Thiocyanide saliva tests or CO content of expired air can be used to confirm smoking status, and exercise treadmill tests with measurement of V_oMax can be used to confirm reported physical activity levels (Stokes, 1983). Thus, most chronic disease risk factors are subject to only limited manipulation by individuals or their health care providers. However, there is a tradeoff between potential "gameability" of risk factors by providers, and invasiveness in gathering risk factor data from beneficiaries. As one relies on physiologic or biochemical measures of risk, in an effort to reduce potential manipulation, the collection of risk factor data becomes more invasive and expensive.

The major disadvantage of using chronic disease risk factors as health status adjusters for AAPCC is the additional administrative burden and costs associated with collection and periodic assessment of risk factors. Data on chronic disease risk factors are not collected routinely for Medicare beneficiaries and cannot be found in any of the existing HCFA data bases. Thus, the use of risk factors for chronic disease in adjusting AAPCC represents an enormous additional administrative burden on the Medicare program.

The administrative burden would be lessened considerably if self-reported risk factor data were collected on enrollment in the Medicare program and periodically thereafter, or if Medicare paid for a periodic health risk assessment for all beneficiaries, the results of which could be reported as part of the bill. However, routine collection of risk factor data should be pursued only as part of a broader strategy of health promotion and disease prevention for the Medicare enrolled population.

The Medicare program must consider whether it would be ethical to require assessment of risk without ensuring followup for persons identified as high risk for chronic disease. There is substantial agreement among public health and medical care professionals that identification of risk without followup is unacceptable. If enrollees or participating physicians are required to routinely report risk levels, and Medicare is willing to pay the additional administrative costs to obtain the necessary data to risk-adjust AAPCC, then the Medicare program should also pay the incremental cost associated with treatment, counseling, and followup for high-risk beneficiaries. A physician who knows a patient is at high risk for chronic morbidity and acute medical care cannot ignore the risk, and yet Medicare is prohibited by section 1862 of the Social Security Act from paying for preventive services to reduce risk levels. The only exceptions to this rule not to pay for

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prevention under the Medicare program are for immunizations and cancer screening for women. As of 1992, Medicare will pay for the pneumococcal pneumonia vaccine, pap smears, and mammography screening. Medicare, however, does not pay for any preventive services to reduce the risk for cardiovascular disease.

Like all of the other factors considered for adjusting AAPCC, the use of chronic disease risk factors would present potential problems in creating perverse provider incentives. Tying capitation payments to elevated risk factors for chronic disease could reduce the role of HMOs in health promotion and disease prevention for the elderly. If chronic disease risk factors are to be considered as a health status adjuster for AAPCC, new incentives must be incorporated into the payment mechanism to encourage—not discourage—reduction in the prevalence of the risk factors in the Medicare enrolled population. While the Medicare program may not choose to dictate how HMOs use additional payments for high risk persons, creating positive incentives to reduce risk levels would at least protect against potentially perverse behavior which ignores or discourages opportunities to promote the health and reduce the incidence of chronic disease among aged Medicare beneficiaries.

McClure (1984) suggests two possible mechanisms for overcoming perverse provider incentives associated with risk-adjustments based on health status. First, make bonus adjustments to HMOs based on changes in the prevalence of the risk factors over time. For example, if the prevalence of risk factors in a group of Medicare HMO enrollees declines, rather than simply reducing the capitation rate for the group, Medicare could at the same time reward the HMO financially for improving the prospective health status of its beneficiaries. Second, Medicare could make public to beneficiaries changes in the prevalence of the risk factors in an HMO. Such a strategy would balance HMO incentives to maintain high prevalence rates to obtain higher capitation with the need to successfully compete with other HMOs and delivery systems on the basis of performance, quality of care, and health status outcomes. HMOs which are successful at risk reduction could use their success as a marketing strategy to attract new enrollees or retain current members.

A final policy consideration important in a decision to use risk factors for chronic disease as the basis for adjusting AAPCC is the issue of confidentiality of risk factor data, and associated concerns over use of risk factor data by others who might discriminate against high risk beneficiaries. Perhaps most critical to beneficiary acceptance of routine collection of data on risk factors is assurances that data on risk will be treated confidentially by health care providers and by HCFA, as any other clinical or medical information collected by the Medicare program.

HCFA's planned demonstration of a health status registry for Medicare beneficiaries provides an excellent opportunity to determine the administrative feasibility of collecting chronic disease risk factor data. This demonstration proposes to collect uniform and comprehensive health status information, including data on chronic disease risk factors, on new Medicare enrollees at age 65. This data base could then be used to verify the findings of this study for a much larger and more representative sample of Medicare enrollees, prior to proceeding with the development of a methodology to incorporate risk for chronic disease into the AAPCC formula.

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